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Deliverable D2

Report on workshop outcomes

LIFE – DYNAMAP
Dynamic Acoustic Mapping – Development of low cost sensors networks for real time noise mapping

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LIST OF KEYWORDS AND ABBREVIATIONS

Keywords

Dissemination

Dynamap Special Session

Events

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Stakeholders

Abbreviations

ANED : Anomalous Noise Events Detection

END : Environmental Noise Directive 2002/49/EC

ICSV : International Conference on Sound and Vibration

EXECUTIVE SUMMARY

This report describes the outcomes of the first special event, named LIFE Dynamap Special Session I, that was held in Florence, on July 16th, in the framework of the International Conference on Sound and Vibration (ICSV 2015 July 12-16, 2015).
This special event is part of Action D2 on dissemination activities and replaced the planned informative workshop, scheduled in Milan in the third quarter of 2015.

The session was addressed to acoustic researchers and transport infrastructures operators. The purpose of the workshop was to inform about the project, solicit the interest of potential dynamic noise mapping users and gather useful suggestions and recommendations to ease the definition of the Dynamap system specifications.

The session was broken down into two parts. In the first part nine presentations were given by beneficiaries to provide a general overview of the LIFE DYNAMAP project. Presentations were focused on the main project actions and gave a clear picture of the state of the art on dynamic noise mapping, including a first estimate of costs.
In the second part of the session a panel discussion was arranged to stimulate the debate and collect observations and remarks from attendees. The panel discussion included three presentations on stakeholders desiderata, benefits and drawbacks of being informed in real time. Presentations were given by Henk Wolfert (Eurocities, NL), Pietro Lucia (Lombardia Region, IT) and Piotr Gaudibert (Bruit Paris, FR). At the beginning of the session a short questionnaire on the same topics was also distributed to attendees to improve their active participation in the workshop.

About 50 persons attended the event. Brochures and other dissemination materials were also distributed to participants.

In this report the outcomes of the session are illustrated, including papers, presentations, questions from participants and answers from lecturers.

ACKNOWLEDGEMENTS

Special thanks to all Dynamap partners and stakeholders for their contribution and active participation in the Dynamap Special Session.

1. INTRODUCTION

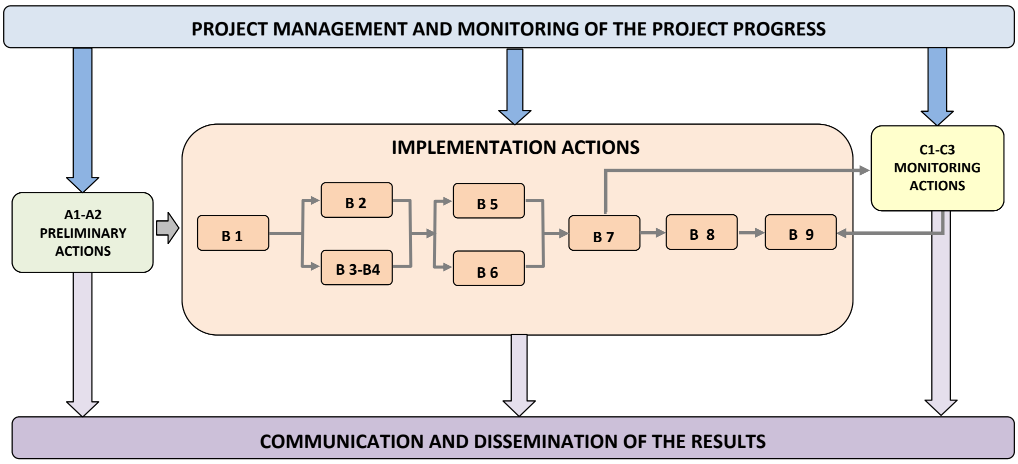
The LIFE DYNAMAP project is a complex five years long project aimed at demonstrating the feasibility of real time noise maps preparation and update using low cost sensors and a general purpose GIS platform. Scope of the project is the European Directive 2002/49/EC (END) relating to the assessment and the management of environmental noise. In particular the project refers to the need for noise maps to be updated every five years, as stated in the END. Nevertheless, the updating of noise maps using a standard approach is time consuming and costly and have a significant impact on the financial statements of the authorities responsible for providing noise maps, such as road administrations and local or central authorities.

To facilitate the updating of noise maps and reduce their economic impact, noise mapping can be automated by developing an integrated system for data acquisition and processing, able to detect and report in real time the acoustic impact of noise sources. The system will be composed of low-cost sensors measuring the sound pressure levels emitted by the noise sources and of a software tool based on a GIS platform able to perform real-time noise maps.

While this approach seems quite promising in areas where noise sources are well identified, such as those close to main roads, in complex scenarios, such as in agglomerations, further consideration is needed to make the idea feasible.

The project will be accomplished through four main steps:

1. Development of low-cost sensors and tools for managing, processing and reporting real-time noise maps on a GIS platform.
2. Design and implementation of two demonstrative systems in the cities of Milan and Rome. The first one will cover a significant portion of the agglomeration of Milan, while the second one will be located along the motorway A90 surrounding the city of Rome.
3. Systems monitoring for at least one year to check criticalities and analyse problems and faults that might occur over the test period. The test results will then be used to suggest system upgrades and extend implementation to other environmental parameters.
4. Provision of a guideline for the design and implementation of real-time noise mapping.



The four steps will be implemented through 14 main actions:

• **2 PREPARATORY ACTIONS (A1-A2)** to collect information on the state of the art of real-time noise mapping, analyse the road networks and locate the areas where the demonstrative systems will be implemented, gather information on the pilot areas.

• **9 IMPLEMENTATION ACTIONS (B1-B9)** to size the monitoring network, develop hardware and software, implement and test the system in the pilot areas, provide a guideline to real-time noise mapping.

• **3 MONITORING ACTIONS (C1-C3)** to assess public response and user ability in consulting and managing the system, evaluate costs and benefits, provide future visions on system applications.

Five more actions have been planned for dissemination and project management, including the arrangement of public events.

This technical report refers to the second Dissemination action “Action D2 – Dissemination activities – Special events”.

2. ACTION D2 – DISSEMINATION – SPECIAL EVENTS

In order to guarantee an effective deployment of the project's results, a series of special events have been scheduled in Action D2, as briefly reported in the following list:

- an informative workshop to promote the project, collate information and exchange opinions. The planned workshop, foreseen in Milan in the third quarter 2015, was replaced by a special session, named Dynamap Special Session I (Fig. 1), arranged in the framework of the International Conference on Sound and Vibration (July 12-16, 2015). The workshop was addressed to representatives of agglomerations and road operators. The main purpose of this workshop was to inform groups of potential users about the project and solicit their interest on dynamic noise mapping. The workshop was focussed on issues directly linked to real time noise mapping and monitoring networks. A clear picture of the state of the art on dynamic noise mapping was given, including a first estimate of costs.

Figure 1 – Dynamap Special session rollup

- A special session, named Dynamap Special Session II, on Noise Monitoring and Mapping with the aim of exchanging information, showing the innovative approach of the DYNAMAP project and collating useful remarks and comments from participants to improve and refine the project before its implementation phase. The Conference, scheduled in the second quarter of 2016, will be delivered in the framework of the International Conference Internoise 2016 that will be held in Hamburg on August 21-24, 2016. Other LIFE+ beneficiaries will be invited to participate in the events and disseminate the results achieved in their projects. Invitations will be also extended to the main stakeholders to solicit their interest and support to the project. Written invitations will be also sent to the desk officer from the Commission and external LIFE project monitor. Information about the event will be sent to the LIFE communication team at least four weeks in advance for advertisement in LIFEnews and LIFE website. About 1500 attendees are expected at the conference. It is envisaged that about 100 participants will attend the Dynamap Special Session. Packs of information documents such as leaflets and brochures will be prepared. During this special event information on the Dynamap system costs will be updated on the basis of real quotes. Local and national press will be also informed and invited to the event to raise awareness around the project. Information will be also delivered through the official website and partners information channels.

- A training course on the Dynamap system. The course will be delivered to ANAS, AMAT and MILAN MUNICIPALITY operators to provide them the necessary skills to manage and maintain the system. The training course will cover several aspects of the developed system and will give all the necessary information on the system set-up and features. The course will be held at the end of the first quarter of 2018. Fourteen people are expected to participate in the training course (10 for ANAS and 4 for MILAN MUNICIPALITY and AMAT).

- A Final Conference, to be held in Rome at the end of the project (last quarter of 2018). In the final Conference the results of the DYNAMAP project will be shown and the Guideline to real time noise mapping will be distributed to participants. Particular emphasis will be given to the cost-benefit analysis results (Action C.2) and a dedicated presentation on the Dynamap system costs will be planned in order to underline the advantage and the economic sustainability of producing dynamic noise maps. Part of the conference will be reserved to other LIFE projects presentations (see also Action E2 on Networking Activities). During the final conference LIFE+ beneficiaries will be invited to participate in the event and disseminate the results achieved in their projects. Invitations will be also extended to the main stakeholders to solicit their interest and support to the project. Written invitations will be also sent to the desk officer from the Commission and external LIFE project monitor. Information about the event will be sent to the LIFE communication team at least four weeks in advance for advertisement in LIFEnews and LIFE website. About 100 attendees are expected. Local and national press will be also informed and invited to the event to raise awareness around the project. Information will be also delivered through the official website and partners information channels.

Finally, Action D2 includes the participation of Milan Municipality and AMAT in two meetings of Eurocities - Working Group Noise to promote the Dynamap project and exchange information with other European local authorities on issues relating to the preparation of strategic noise maps.
In fig. 2 is shown a preliminary plan of dissemination activities among partners, with the estimated number of the expected attendees per event**.**

Year	Quarter	Dissemination events and activities	Name of the Event/Journal/Magazine	Location of the event	number of attendants expected
2015	3	Dynamap Special Session I (Informative workshop)	ICSV 2015	Florence	50
2016	2	Dynamap Special Session	Internoise 2016	Germany	1500
	4	Workshop on Eurocities winter meeting	Eurocities meeting	EU	30
2018	1	Dynamap Training Course		Rome	14
	2	Workshop on Eurocities spring meeting	Eurocities meeting	EU	30
	4	Dynamap Final Event		Rome	100

Figure 2 - Plan of dissemination activities.

3. DYNAMAP SPECIAL SESSION I PROGRAMME

The Dynamap Special Session was broken down into two parts. In the first part nine presentations were given by beneficiaries to provide a general overview of the LIFE DYNAMAP project. Presentations were focused on the main project actions and gave a clear picture of the state of the art on dynamic noise mapping, including a first estimate of costs.
In the second part of the session a panel discussion was arranged to stimulate the debate and collect observations and remarks from attendees. The panel discussion included three presentations on stakeholders desiderata, benefits and drawbacks of being informed in real time.

The session was structured according to the following programme.

T05.SS02

DYNAMAP SPECIAL SESSION I

16 JUNE 2015

Room R05

Programme

08:00 THE LIFE DYNAMAP PROJECT: TOWARDS THE FUTURE OF REAL TIME NOISE MAPPING
Patrizia Bellucci

08:20 STATE OF ART ON REAL TIME NOISE MAPPING SYSTEM AND RELATED SOFTWARE DEVELOPMENT
Andrea Cerniglia

08:40 THE LIFE DYNAMAP PROJECT: AUTOMATING THE PROCESS FOR PILOT AREAS LOCATION
Simone Radaelli, Annalisa Giovannetti

09:00 DYNAMAP: SENSITIVITY ANALYSIS OF THE ACOUSTIC CALCULATION MODEL WITH RESPECT TO ENVIRONMENTAL VARIABLES INSIDE AND OUTSIDE URBAN AREAS
Alessandro Bisceglie

09:20 TRAFFIC NOISE MONITORING IN THE CITY OF MILAN: CONSTRUCTION OF A REPRESENTATIVE STATISTICAL COLLECTION OF ACOUSTIC TRENDS
Fabio Angelini

09:40 DEVELOPMENT OF OPTIMIZED ALGORITHMS FOR THE CLASSIFICATION OF NETWORKS OF ROAD STRETCHES INTO HOMOGENEOUS CLUSTERS IN URBAN AREAS
Giovanni Zambon

10:00 Coffee Break

10:20 PLENARY LECTURE
Semyung Wang

11:20 DYNAMAP MONITORING NETWORK HARDWARE DEVELOPMENT
Luca Nencini

11:40 DEVELOPMENT OF AN ANOMALOUS NOISE EVENT DETECTION ALGORITHM FOR DYNAMIC ROAD TRAFFIC NOISE MAPPING
Joan Claudi Socoró

12:00 BASIC SECONDARY ASPECTS OF THE LIFE DYNAMAP PROJECT
Laura Peruzzi

12:20 Panel Discussion
Stakeholders' desiderata – *What stakeholders would like dynamic maps should do.*
The perspective of Eurocities (Henk Wolfert) and Lombardia Region (Pietro Lucia)
Why dynamic noise maps?- *The benefits and drawbacks of being informed in real time*.
The experience of Harmonica (Piotr Gaudibert)

13:00 End of the Session

4. RUNNING OF THE SESSION

The session opened with a brief welcome speech (Fig. 3) made by the project manager Patrizia Bellucci and proceeded with the first presentation, where a general overview of the project is provided and the key aspects were introduced (Fig. 4).

Figure 3 - Welcome to the Dynamap Special Session.

The session moved on with presentations describing the state of art on real time noise mapping and the automatic procedure used to locate the pilot areas, where the Dynamap system will be installed.

At the end of the presentation of the fourth topic, related to the sensitivity analysis of the acoustic calculation model with respect to environmental variables inside and outside urban areas, questions on the possibility of using different models from XPS 31-133 (NMPB algorithm) to estimate road traffic noise, with a direct reference to CNOSSOS (recently published by the European Commission) were raised. In particular, the questions were focused on the different approach to calculate the influence of meteorological conditions on noise propagation. The lecturer replied that the possibility of adopting the algorithm CNOSSOS after assessing any significant differences compared to NMPB will be considered.

In the next presentations, the main issues related to the pilot area of Milan were illustrated They included the identification of road noise trends and the development of optimized algorithms for the classification of the road networks stretches into homogeneous clusters.

After the coffee break and the plenary lecture, the session moves on with presentations on issues related to hardware and software development. These include also an algorithm, named ANED (Anomalous Noise Events Detection), for the detection and removal of anomalous noise events. At the end of the presentation questions on the relevance of the algorithm, in terms of measured equivalent sound level, were raised. The lecturer replied that the algorithm was tested with synthetic mixtures and that the real impact will be estimated only when data from Milan and Rome will be available.

Figure 4 - Presentation of the Life Dynamap project.

Finally a presentation about basic secondary aspects of the Life Dynamap project was given. The attention of attendees was mainly attracted by the estimated costs of the system and items included in the calculation (the cost of the monitoring stations, their installation and maintenance for twenty years, the cost related to the preparation of the basic noise maps). The lecturer replied to questions by underlying that just a first rough estimate of the dynamic noise mapping costs was accomplished, on the basis of the expense that should be paid in the Dynamap project to prepare the pilot area located in Rome. However it was highlighted that during the project the cost estimate will be constantly updated.

The session ended with a Panel Discussion with presentations given by Henk Wolfert (Eurocities, NL), Pietro Lucia (Lombardia Region, IT) and Piotr Gaudibert (Bruit Paris, FR) about what stakeholders would like dynamic maps should do and the benefits and drawbacks of being informed in real time.

A copy of the nine submitted papers and related presentations is available in Appendix 1 - Dynamap special session papers and in Appendix 2 - Dynamap special session presentations.

5. DYNAMAP QUESTIONNAIRE

During the Dynamap Special Session a questionnaire was distributed to participants, with the aim to collate opinions, comments and suggestions on what dynamic noise maps should be and report, as well as the benefits and drawbacks of being informed in real time.

The questionnaire was broken down into two sections, covering the same topics raised during the panel discussion:

- Stakeholders' desiderata – What stakeholders would like dynamic maps should do.
- Why dynamic noise maps? - The benefits and drawbacks of being informed in real time.

The questionnaire reported a series of options that the user can select and some blank boxes for adding suggestions, comments and opinions.

Few feedbacks were received from the Dynamap Special Session attendees, so that it was decided to send the questionnaire by e-mail to selected groups of stakeholders, i.e. the Noise Group of Eurocities and the Road Noise Group of CEDR, the Conference of European Directors of Roads. Replies are expected by the end of February 2016.

The questionnaire format is showed below.

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

QUESTIONNAIRE
What you would like the Dynamap System will do

General Information

Country	
Organization	
Name and Surname	
e-mail	

Part 1

Stakeholders' desiderata – *What stakeholders would like dynamic maps should do.*

Parameters to be monitored in real time and saved:

- ☐ Sound Pressure Levels;
- ☐ Traffic Volume and Composition;
- ☐ Traffic speed;
- ☐ Traffic flow conditions (free flowing, interrupted, accelerated, decelerated);
- ☐ Anomalous events;
- ☐ Basic weather conditions (temperature, wind speed and direction, rain);
- ☐ Additional weather conditions (fog, snow and hail);
- ☐ Air pollutant concentrations (CO, CO_2, NO,NO_2, NO_x, SO_2, PM_{10}, $PM_{2.5}$, O_3, HC, Pb);
- ☐ Other (to be specified).

Parameters to be calculated off line:

- ☐ Hourly data (Time history);
- ☐ Day, evening and night data;
- ☐ Lden data;
- ☐ Weekly data (day and night, only for the Italian legislation);
- ☐ People exposed to noise level intervals;
- ☐ Conflict values;
- ☐ L95 and L90;
- ☐ Number and type of anomalous events;
- ☐ Other (to be specified)

Data to be published for public information and communication:

- ☐ Dynamic noise maps;

- Weekly day and night maps/values;
- Limit values and conflict values;
- Quiet areas;
- Weather information;
- Traffic information;
- Air quality information;
- Public questionnaires;
- General educational information on noise issues and driving style suggestions to reduce the noise impact;
- A form to communicate with the system manager to ease the participation of the public during the preparation of the action plan.
- Development of an app to make the access to the system easier;
- Other (to be specified).

Part 2

Why dynamic noise maps?- *The benefits and drawbacks of being informed in real time.*

How frequently noise maps should be updated in your view?

What kind of benefits do you think could be attributed to dynamic noise maps?

What kind of technical drawbacks or problems could dynamic noise maps show in your opinion?

What kind of social drawbacks could emerge from being informed in real time?

APPENDIX 1 - Dynamap special session papers

THE LIFE DYNAMAP PROJECT: TOWARDS THE FUTURE OF REAL TIME NOISE MAPPING
P.Bellucci, L.Peruzzi, G.Zambon

STATE OF THE ART ON REAL TIME NOISE MAPPING SYSTEM AND RELATED SOFTWARE DEVELOPMENT
Andrea Cerniglia

THE LIFE DYNAMAP PROJECT: AUTOMATING THE PROCESS FOR PILOT AREAS LOCATION
P.Coppi, S.Radaelli, A.Giovannetti, R.Grecco

DYNAMAP: SENSITIVITY ANALYSIS OF THE ACOUSTIC CALCULATION MODEL WITH RESPECT TO ENVIRONMENTAL VARIABLES INSIDE AND OUTSIDE URBAN AREAS
G.Zambon, A.Bisceglie, S.Radaelli

TRAFFIC NOISE MONITORING IN THE CITY OF MILAN: CONSTRUCTION OF A REPRESENTATIVE STATISTICAL COLLECTION OF ACOUSTIC TRENDS
F.Angelini, G.Zambon, D.Salvi, W.Zanaboni, M.Smiraglia

DEVELOPMENT OF OPTIMIZED ALGORITHMS FOR THE CLASSIFICATION OF NETWORKS OF ROAD STRETCHES INTO HOMOGENEOUS CLUSTERS IN URBAN AREAS
G.Zambon, R.Benocci, A.Bisceglie

DYNAMAP MONITORING NETWORK HARDWARE DEVELOPMENT
Luca Nencini

DEVELOPMENT OF AN ANOMALOUS NOISE EVENT DETECTION ALGORITHM FOR DYNAMIC ROAD TRAFFIC NOISE MAPPING
J.C.Socoró, G.Ribera, F.Alías, X.Sevillano

BASIC SECONDARY ASPECTS OF THE LIFE DYNAMAP PROJECT
P.Bellucci, L.Peruzzi, G.Zambon, X.Sevillano

THE LIFE DYNAMAP PROJECT: TOWARDS THE FUTURE OF REAL TIME NOISE MAPPING

Patrizia Bellucci and Laura Peruzzi

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The Environmental Noise Directive (END) requires that regular updating of noise maps is implemented every five years to check and report about the changes occurred during the reference period. The updating process is usually achieved using a standardized approach, consisting in collating and processing information through acoustic models to produce the updated maps. This procedure is time consuming and costly, and has a significant impact on the budget of the authorities responsible for providing the maps. Furthermore, END requires that simplified and easy-to-read noise maps are made available to inform the public about noise levels and actions to be undertaken by local and central authorities to reduce noise Impacts. To make the updating of noise maps easier and more cost effective, there is a need for integrated systems that incorporate real-time measurement and processing to assess the acoustic impact of noise sources. To that end, a dedicated project, named DYNAMAP, has been proposed and co-financed in the framework of the LIFE 2013 program, with the aim to develop a dynamic noise mapping system able to detect and represent in real time the acoustic impact of road infrastructures. In this paper, a comprehensive description of the project idea, objectives and expected results is presented to inform about the potential breakthrough of the proposed solution.

1. Introduction

Dynamap is a Life+ project aimed at developing a dynamic noise mapping system able to detect and represent in real time the acoustic impact due to road infrastructures. Scope of the project is the Directive 2002/49/EC (END) of the European Parliament and of the Council relating to the assessment and management of environmental noise [1]. Aim of the Directive is to define a common approach intended to avoid, prevent or reduce the harmful effects due to exposure to environmental noise. To that end, noise maps must be provided and updated every five years in order to report about changes in environmental conditions (mainly traffic, mobility and urban development) that may have occurred over the reference period.

The updating of noise maps using a standard approach requires that authorities responsible for providing noise maps collect and process new data related to such changes. This procedure is time consuming and costly and has a significant impact on the financial statements of the authorities responsible for providing noise maps. As a matter of fact, many road administrations and local authorities are complaining about the huge financial effort of noise mapping activities. For this reason, the need for reducing costs, especially in conjunction with the current economic crisis affecting several European countries, has become a primary objective. Such a concern was also confirmed by the working group Road Noise of the Conference of European Directors of Roads (CEDR) in the report on END Noise Mapping (2013)[2]. In addition, the application of administrative penalties in some Member States makes this need far more urgent. As a consequence, a solution to reduce the resources necessary to update noise maps was solicited by CEDR in their report on “Road Noise Research Needs” [3] with high priority.

To facilitate the updating of noise maps and reduce their economic impact, noise mapping can be automated by developing an integrated system for data acquisition and processing that is able to detect and report in real time the acoustic climate due to noise sources. This approach seems quite promising in areas where noise sources are well identified, such as those close to main roads. In complex scenarios, such as in agglomerations, further considerations and testing are needed to make the idea feasible.

Furthermore, the END states that simplified and easy-to-read noise maps are made available to inform the public about noise levels and actions to be undertaken by local and central authorities to reduce the noise impact on the environment. To that end, a suitable on-line database will be equipped with different access levels to deliver simplified data for the public and different levels of information to skilled and authorised users.

Finally, a more integrated approach to environmental monitoring would be desirable, in order to achieve a comprehensive and complete overview of the environmental impact of infrastructures. For this purpose, the system will be also designed so as to be adaptable to other kind of sensors detecting information requiring periodic assessment, such as traffic data, air quality, meteorological and road conditions.

2. State of the art on dynamic noise mapping

Dynamic noise maps are acoustic maps automatically updated using measured data provided by monitoring stations located close to sound sources, such as roads, rails and industrial plants. This application is now days extremely fast as no further recalculation of the sound propagation is needed to adapt the noise map to the measured data. The monitoring stations are installed at relevant receiver locations where sound pressure levels are dominated by sources. For each of the monitored source a complete noise map covering the entire mapping area is calculated and saved.

Noise maps updating is achieved scaling the noise levels of pre-calculated (basic) noise maps as a function of the difference observed between measured and calculated original grid data. This operation is provided for each source present in the mapping area. The updated total map is achieved by energetic summation of single source updated noise maps. The updating process can either be based on traffic count data or other source parameters.

The idea of linking the output of sound level meters to noise calculation models to produce automatic and updated noise maps was developed some years ago.

In 2003 Madrid Environmental Administration, together with Brüel&Kjær, decided to develop a new concept of data post-processing, based on dynamic noise maps or SADMAM (Sistema Actualización Dinámica Mapa Acústico Madrid) [4,5]. Mobile monitoring devices equipped with GIS systems were used to measure sound pressure levels at strategic locations. For this purpose, Madrid invested in a system including the Noise Calculation Software Lima and several Noise Monitoring Terminals. This approach was supposed to support Madrid City Council to efficiently validate and improve the quality of the strategic noise maps, which would have form the basis of the action plan required by EU Noise Directive 2002/49/EC, raising public confidence in the maps and avoiding unnecessary actions based on incorrect results.

Some critical aspects are evident in this approach. First of all the need of mobile monitoring devices to sample sound pressure levels, that makes the solution quite expensive and unsuitable to automatic noise maps updating. Secondly, no algorithm for eliminating spurious events are used to guarantee data reliability and provide accurate maps. In addition, very complicated and time consuming algorithm and software are implemented to update noise maps, thus drastically reducing the possibility of upgrading the system to real time operations.

In the meantime ACCON developed a simple system based on pre-computed maps linked to standard noise monitoring stations, but without any capability of partial maps summing, and without any user-friendly GIS interface for data presentation [6].

At present, a limited number of acoustic software producers provides interface modules to link sound level meters to acoustic simulation applications [7]. These modules need to run continuously in their original environment (the main simulation software) that is, unfortunately, usually quite expensive. In addition, for each investigated area a software license is needed, whereby if many noise areas were to be mapped, a very large number of licenses would be necessary. Furthermore, to update noise maps several noise monitoring stations should be interfaced (depending on the extension and complexity of the area) to scale the pre-calculated maps, thus contributing to increase the overall cost of the system. Therefore, this application, although extremely appealing from a technical perspective, sounds to be extremely expensive and, as a consequence, inapplicable on a large scale.

3. The project idea

The main project idea is focused on the research of a technical solution able to ease and reduce the cost of periodically updating noise maps, through an automatic monitoring system, based on customised low-cost sensors, and a software tool implemented on a general purpose GIS platform performing the update of noise maps in real time (dynamic noise maps).

The update of noise maps can be rapidly accomplished by scaling pre-calculated basic noise maps, prepared for different sources, traffic and weather conditions. Basic noise maps are selected and scaled using the information retrieved from low-cost sensors continuously measuring the sound pressure levels of the primary noise sources present in the area to be mapped. In order to guarantee the accuracy of the updating process, noise levels are first cleaned up from anomalous events before being used to scale the basic noise maps. Scaled basic noise maps of each primary source are then summed-up to provide the overall noise map of the area. In this way, the need for several and expensive software license is extremely reduced and limited only to the preparation of the basic noise maps.

The idea of developing and implementing a low cost monitoring network came from another interesting experience gained in the project SENSEable PISA (Italy - 2011), where large volumes of environmental data were gathered to extrapolate information on public health, urban mobility, air pollution, etc., using appropriate mathematical tools (data mining). To accomplish this task low cost sensors and data transmission devices were developed [8, 0].

Being inspired by this general idea, the system foreseen in the DYNAMAP project includes the development of customized low cost devices to collate and transmit data, and the implementation of a simple GIS based software application for maps scaling with reduced calculation load. Such a standalone dynamic mapping software (no need of running modelling software), together with low cost noise monitoring stations, makes the DYNAMAP system a very efficient and versatile noise mapping tool, virtually able to interface any existing or future noise modelling software, including the new European model CNOSSOS, which is expected to be operative for the next round of END.

The DYNAMAP system includes also some unique characteristics that are not available in commercial products, like algorithms for eliminating spurious events (recognizing and masking unwanted events: i.e. occasional noise, etc.), traffic model data features, and future adaptability to other environmental parameters.

In Fig. 1 a schematic representation of the DYNAMAP system is shown.

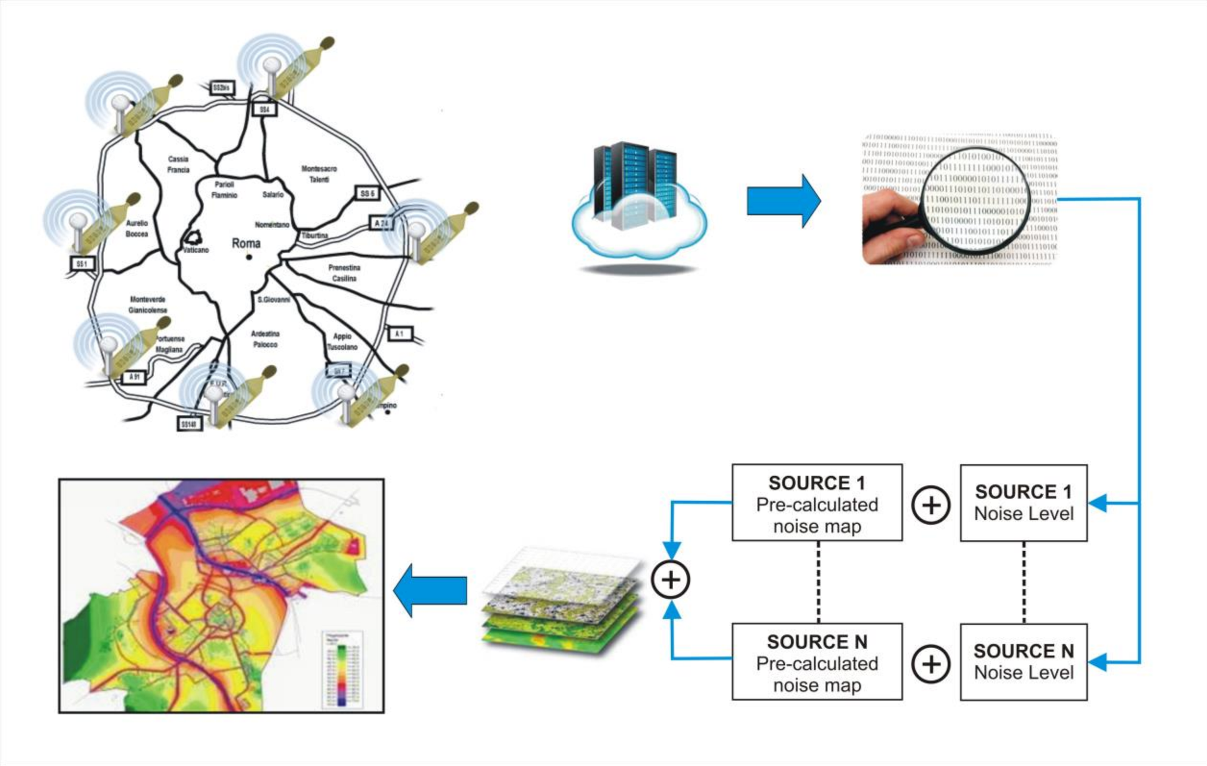

Figure 1. Schematic representation of the DYNAMAP system.

4. The project objectives

The main goal of the project is to demonstrate that noise maps can be automatically updated in real time using low cost sensors and a general purpose GIS platform. The noise levels detected by the sensors will be used to scale noise maps stored in the system database. To that end, customized sensors and communication devices will be developed, in order to reduce the cost of monitoring the road network. An advanced management and reporting interface will be designed to update noise maps and inform the public. Such an interface will be based on a general purpose GIS platform, thus eliminating the need for expensive dedicated acoustic software for data processing.

The feasibility of this approach will be proved implementing the systems in two pilot areas with different territorial and environmental characteristics: an agglomeration and a major road.

The first pilot area will be located in the city of Milan and will cover a significant portion of the town including different type of roads and acoustical scenarios. Roads will be classified and assigned to three clusters, based on traffic characteristics. Twenty four roads representative of the clusters will be continuously monitored to provide noise levels for noise maps updating. Traffic data collected by on site available vehicles counting devices will be integrated in the dynamic noise mapping system to improve and refine noise maps with real traffic information.

The second pilot area will be located along a major road, i.e. the ring road surrounding the city of Rome. Sensors devices will be installed in hot spots where traffic counting is unavailable to feed the dynamic mapping system with real time information on noise levels. About 25 devices will be used to provide noise levels information alongside the road and dynamically update the noise maps.

The two pilot areas will be monitored for at least one year to check the reliability and accuracy of the system. Static maps accomplished using standard acoustic models and software will be compared with those provided by the Dynamap system. Fault events will be also analysed in order to detect system malfunctions and define the specifications for future system and devices upgrade.

As a secondary objective, the project aims at demonstrating that dynamic mapping can be also applied to monitor and report the information related to other environmental parameters, such as those related to air quality, meteorological conditions, traffic, etc. Integrated information can be effectively used by decision makers to monitor polluted areas and take the appropriate actions to restore critical situations. To test this option, two monitoring sites will be equipped with additional sensors to assess the feasibility of feeding and integrating the dynamic mapping system with multiple information.

Finally, the Dynamap system will be also equipped with a GIS web software application to inform the public on noise issues. A group of selected users will be monitored to check the accessibility of the system and help developing a user-friendly interface for public information. The system will be validated by testing stakeholders ability in managing the tool and assessing their agreement through ad hoc tutorials. Case studies related to the most common environmental problems will be proposed in order to assess the effectiveness of the dynamic mapping system.

The general public will be also involved in the project monitoring to evaluate the system versatility and its contents comprehensibility. A sample of people with different age will be used to take into account the diverse background and ability in managing computers and software applications. Assisted and stand-alone tests will be provided in order to check people reactions to the specific system application.

5. The project structure

The project will be accomplished through four main steps:

1. Development of low cost sensors and tools for the management, processing and reporting of real time noise maps on a GIS platform.
2. Design and implementation of two demonstrative systems in the cities of Milan and Rome.
3. Systems monitoring for at least one year to check criticalities, analyse problems and faults that might occur over the test period. Test results will then be used to suggest system upgrade and to extend its implementation to other environmental parameters.
4. Provision of a guideline for the design and implementation of real time noise mapping.

The four steps will be implemented through 14 main actions (Fig. 2):

- 2 preparatory actions to collect information on the state of the art of real time noise mapping, analyse the road networks and find areas to be used for implementing the demonstrative systems, acquire information on the pilot areas.
- 9 implementation actions to size the monitoring network, develop hardware and software, implement and test the system in the pilot areas, provide a guideline to real time noise mapping.
- 3 monitoring actions to assess public response and user ability in consulting and managing the system, evaluate costs and benefits, provide future visions on system applications.

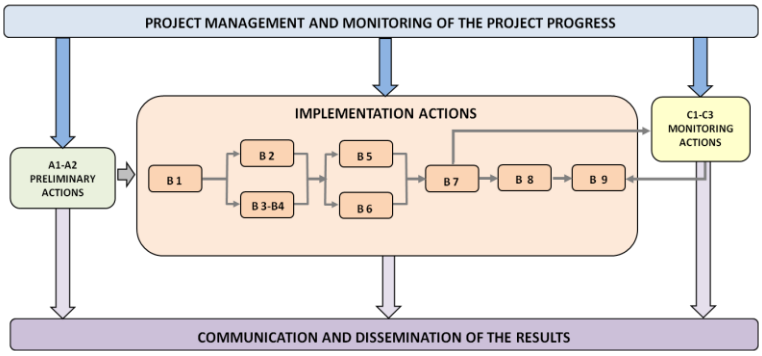

Figure 2. Main actions.

6. Expected results

The project is expected to provide seven main deliverables:

1. Development of low cost sensors to measure the noise levels generated by the sources included in the mapping areas. A cost reduction of about 50% for noise mapping activities is expected by implementing the Dynamap System.
2. Development of a software tool for dynamic noise mapping – Data retrieved from sensors will be sent to a data management system, through a dedicated software application for real time data managing and processing.
3. Implementation of two demonstrative systems – The system will be installed and tested in two different sites: the first one located inside the agglomeration of Milan and the second one along a major road surrounding the city of Rome.
4. Test results of the systems – The system will be tested for one year in order to assess its reliability, detect and solve problems, determine its accuracy and calculate the uncertainty associated to noise maps.
5. System upgrade feasibility – The possibility of strengthen the system with applications for dynamically reporting integrated environmental impacts (noise, air quality, meteorological conditions, etc.), will be analysed.
6. Test results on public response and user ability in consulting and managing the system – The software tool will be structured with different data access levels based on the privileges assigned to users. The tool will be tested to check the public response and user ability in consulting and managing the system.
7. Dissemination – The project will provide for an extensive dissemination campaign based on traditional and web communication channels, such as conferences, seminars, workshops, papers, a dedicated website, social networks and forums.

7. Added value of the project

The main added value that can be attributed to the project is the potential reduction of the financial effort required to central and local authorities to provide updated noise maps. The huge economic burden associated to the preparation of reliable noise maps is also made stronger by the presence, in some Member States, of administrative penalties that are applied in case END requirements are not met. As a consequence, the need for reducing costs, especially in conjunction with the current economic crisis, has become a primary objective.

The automation of the noise mapping process using a low cost monitoring network and a software application implemented in a general purpose GIS platform, will contribute to abate costs and reduce the time needed to update noise maps, regardless of territorial contexts and geographical areas, thus making the measure suitable to all European Countries.

In the past, this solution was partially tested on small areas by means of standard sound level meters and expensive acoustic software, but it has never been tested at a large scale with low cost customized devices and a general purpose GIS platform for data processing and system management.

Another issue that makes the Dynamap System particularly valuable is the possibility of providing immediate actions in case high noise levels are reached. The real time monitoring of noise levels can be effectively used to generate alert signals and drive ITS systems interface to smooth traffic, for instance by remote control of speed limits, heavy vehicles banning, etc. Taking into account that about 75% of the receivers living close by the road networks are impacted by noise levels that do not exceed noise limits for more than 3 dB(A), mitigation measures based on ITS could be effectively used to bring sound pressure levels below the noise threshold. As a consequence of such measures, a noise reduction of 2-3 dB(A) can be expected when interfacing the Dynamap System with appropriate ITS systems.

8. Expected benefits

The Dynamap project is expected to impact mainly authorities responsible for complying with END obligations and, in particular, those appointed for providing updated noise maps for major roads and agglomerations at local and national level. As one of the main objectives of the project is to reduce the economic impact related to data collection and processing to update noise maps, the implementation of the project at a large scale will effectively contribute to abate the financial burden of public administrations.

From a social and environmental perspective, the project will also provide:

- a real time update of noise maps as a consequence of the mapping process automation;
- a reduction of the sites to be noise mapped with traditional tools and expensive monitoring campaigns to collect input data, now limited to new or changed residential areas;
- a faster response to noise mitigation requests, thanks to the real time availability of updated dynamic maps;
- a prompt response to alert events associated to specific noise thresholds through interface devices to ITS systems (for instance, speed limit reduction, traffic calming, etc.);
- a more comprehensive and reliable information on the environmental impact due to traffic, based on the number and type of additional sensors used to monitor the road network;
- a user-friendly tool for informing the public about noise pollution and other environmental issues.

9. Conclusions

In this paper, a comprehensive description of the Life Dynamap project is presented. The project involves the development of a dynamic noise mapping system able to detect and represent in real time the acoustic climate of road infrastructures.

The system will be composed of customized low cost sensors, measuring the sound pressure level of the noise sources present in the area to be mapped, and of a software tool, based on a GIS platform, able to automatically update noise maps in real time. The main goal of the project is to reduce the cost of the noise mapping process and to provide the authorities responsible for noise mapping activities with affordable and ready to use noise maps.

The system will be installed and tested in two very different sites: the first one located inside the agglomeration of Milan and the second one along a major road surrounding the city of Rome to assess its reliability and accuracy.

A dramatically reduced economic burden of noise mapping activities is expected from the DYNAMAP System, as well as more accurate and ready to use noise maps.

To conclude, it is envisaged that the idea of distributing low cost sensors to dynamically update noise maps will contribute in the future to enlarge the number of measured receivers, ideally extending the monitoring network to the whole territory to be noise mapped, with the advantage of ensuring updated and more reliable results.

ACKNOWLEDGEMENTS

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STATE OF ART ON REAL TIME NOISE MAPPING SYSTEM AND RELATED SOFTWARE DEVELOPMENT

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Automatic noise maps calculation is an attractive tool for both infrastructures administrations which -according to END- should produce noise maps and action plans every 5 years, and for citizens who wants to know how healthy is their living place in terms of noise pollution; this last aspect has become more evident during the last years, where great efforts have been made to spread information on the long-term risk of living in a noise-polluted environment. In the last few years some approach to dynamic noise map were attempted, but the high implementation costs bordered most of those project just in research field. The article investigates the state of the art of real-time noise mapping and related software development.

1. Introduction

Exposure of citizens to noise is a widely recognized problem, which also involves important social costs for health [1][2]. For this reason citizens are interested in knowing how healthy is their living place in terms of noise pollution. Figure 1 shows a map of Europe [3] showing per-country percentage of respondents answering "*Yes*" to question "*In the immediate neighbourhood of your home do you have reason to complain about noise?*". Above mentioned aspect, together with the high costs which infrastructures administrations has to invest for the EC/2002/49 requirement [4] for producing updated noise maps every five years, triggered the needs for cheap dynamic noise mapping system.

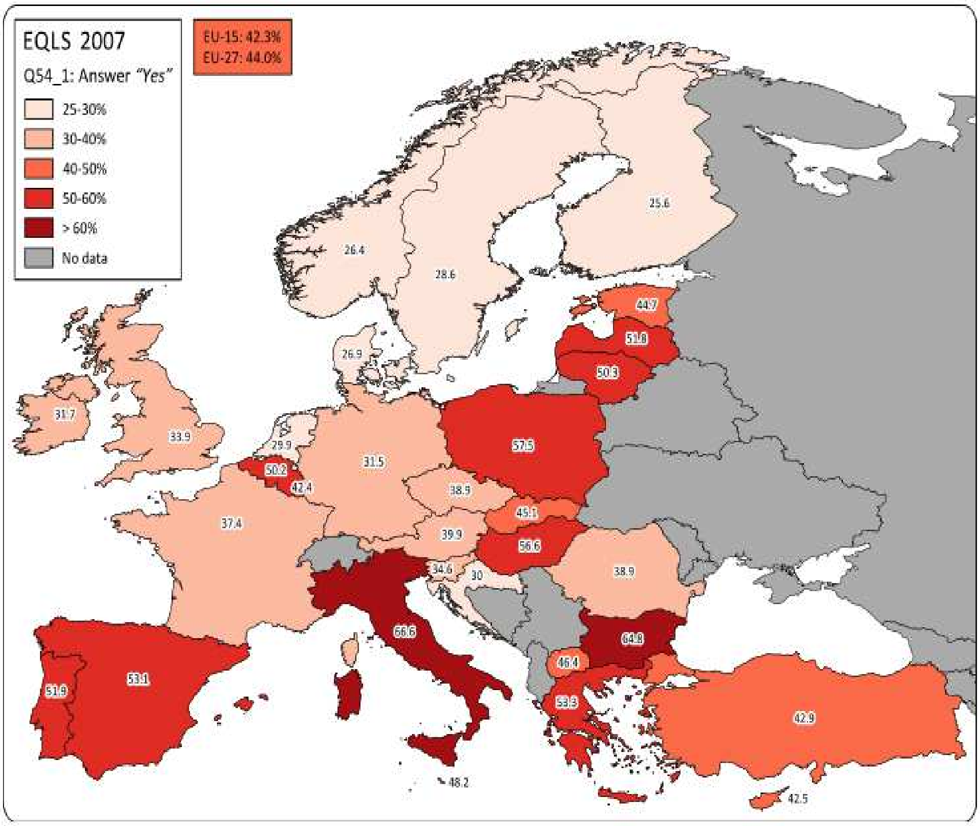

Figure 1. Map of Europe showing 'noise compliant'

2. Principle of operation of real time noise mapping

The usual approach to Real Time Noise Mapping consists in implementing a localized standard noise monitoring network, which continuously collects noise data, and transmits them to a data centre in which a noise mapping software is running. The role of the mapping software is to compute noise maps according the information coming from noise monitoring network, or to re-scale pre-computed partial noise maps taking into account to the incoming noise data, and sum them together in order to obtain the whole area updated noise map; in each case the idea is to publish results continuously on a web site. Of course it is a must that each noise monitoring terminal is influenced by only one road section to which the partial map is referred. Although during the last years the price of sound level meters has decreased and their features highly improved, noise monitoring terminals are still quite expensive, so that building up a monitoring network can be rather costly. This is one of the reasons why software manufacturers have not invested too much in developing dynamic noise mapping so far. In addition to the above mentioned approaches, some others technique were developed during last years to obtain real time dynamic noise map. In the following, main dynamic noise map approaches are discussed.

3. Approaches to real time noise mapping

The Dynamap report on the state of the art of dynamic noise mapping [5], analyzes some systems developed by various organizations during the last years. Table 1 summarize, in alphabetic order, the analyzed system and the approach on which they are based, while next sections examines more in details the implemented technologies.

Table 1. Analyzed systems

System	Type
ACCON	Scaling and sum of pre-computed maps
Datakustik	Scaling and sum of pre-computed maps
Gdansk University	On-line calculation
GEIART	Cluster analysis on traffic model
Ghent	Simplified on-line calculation
IDASC CNR	Scaling of pre-computed maps
Laermometer	Citizens contributive mobile noise mapping (smartphone)
NoiseMote	Low cost sensor system
NoiseTube	Citizens contributive mobile noise mapping (smartphone)
NPL	Low cost sensor system
SADMAM	Scaling and sum of pre-computed maps

As shown in the table, there are three major approaches to dynamic noise maps: on-line calculation, map re-scaling and sum, and citizens contributive; the system called GEIART is slightly different from the above, as it do not directly measure noise levels for updating a noise model, while it implement vehicle counting to update a traffic model which drive to updated noise maps. In addition to the above, also few low cost monitoring system are presented.

3.1 On-line calculation approach

Figure 2 shows a typical configuration of a dynamic noise mapping system. The same setup shown in the picture is used also for scale and sum approach described in the next section, but with a different role of the noise model server.

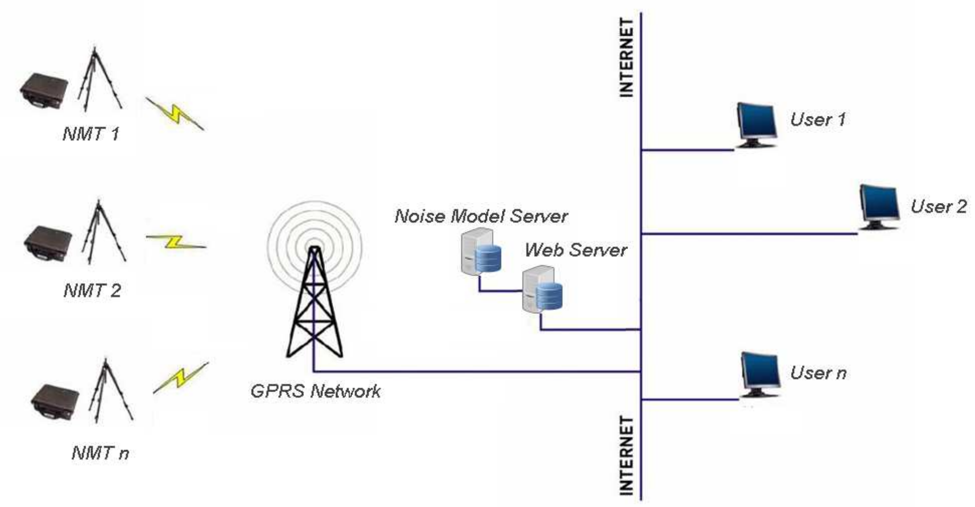

Figure 2. Typical setup for noise mapping system

In real time calculation approach, the measured values coming from noise monitoring network, are used as input data for the noise simulation software, to perform new calculation of noise maps. So, due to the fact that the role of the noise model server is to recalculate a complete noise map with continue update, in order to perform this job the noise model software should run continuously on a very powerful machine, which should make calculation as fast as possible. Gdansk university developed their system using this technology [6][7].

The use of simplified calculation algorithms can lead to fast map updating. Ghent university used this last approach to make their own system [8].

3.2 Map scaling and sum approach

This approach use a similar infrastructure as on-line calculation approach, but with a different role of the noise mapping server. In this case the new map is computed just as the sum of re-scaled pre-calculated maps, according to the measured noise levels. As all calculation toke place once at system startup, maps update rate can be very fast. This technology is implemented in systems developed by ACCON[9][10], IDASC[11], DATAKUSTIK and SADMAM [12][13].

With this technology two 'sub-approaches' are possible; the first uses a function implemented inside the noise model software for scaling and summing the partial maps, while the second one uses an external GIS software to do the job, as no any ray tracing is needed to obtain new maps.

Figure 3 shows the dynamic noise map web page of Gräfelfing community (D), which use the GIS software technique and was implemented by ACCON.

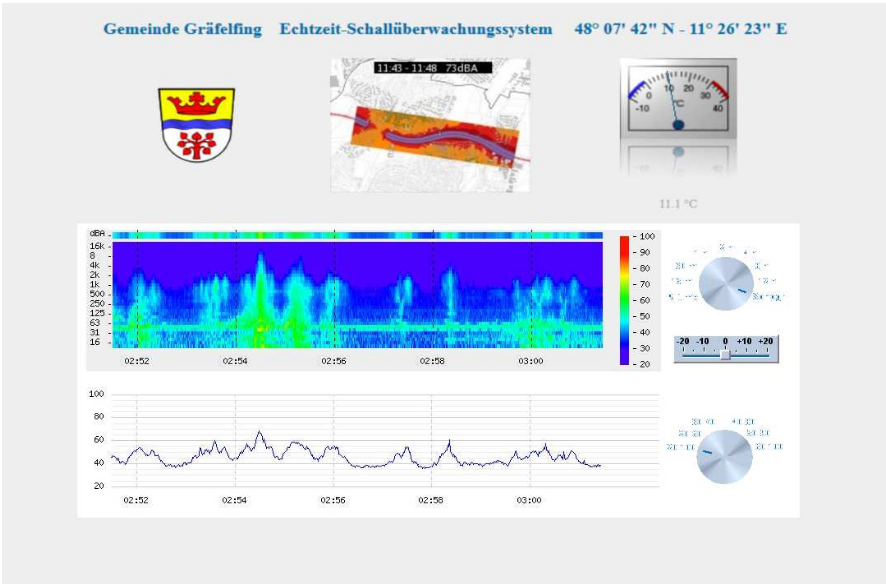

Figure 3. Gräfelfing Dynamic Noise Map page

3.3 Citizens contribution

Thanks to the high diffusion of smartphones, a new technology for dynamic noise mapping started few years ago. Main idea behind this technology is to use citizens' smartphones to take many measurements inside a city, and build up a noise map based on the acquired noise levels by citizens.

Two examples of this technology are Laermometer [14] and NoiseTube [15]. In both cases acquired noise data, together with localisation coming from smartphone embedded GPS system, are sent by cellular phone to a web server able to manage data and present them as noise maps, also directly by using Google Earth platform.

3.4 Low cost noise monitoring terminals

Between 2004 and 2007 NPL developed DREAMSys (Distributed Remote Environmental Array & Monitoring System), a low cost monitoring system based on new MEMs microphones [16][17]. DREAMSys units are capable of measuring both A-weighted and C-weighted equivalent continuous sound pressure levels, over a user-defined period from a few seconds upwards, as well as a number of statistical parameters including the maximum A-weighted level, and three percentile levels, which can also be programmed. A comprehensive database and a set of visualisation tools were produced to manage and present data.

In 2011 a project called SensablePisa started. The idea behind the project was to implement a cheap noise monitoring network for the city of Pisa, involving citizens who agreed to host developed sensors with the aim of sharing the measured values in a virtual community[18][19]. Façade noise levels were posted in real time on a dedicated website and on Facebook and Twitter social networks, while all historical noise data were collected in a central remote server. Noise map was limited to the values in measured positions. From this project, a sensor named NoiseMote was developed, and the acquired experience converged now in Dynamap project for the development of a improoved noise sensor and related network.

4. Dynamap system

Dynamap project, based on the above mentioned scaling and sum technology, consider some important aspects for obtaining cheap, fast and reliable system, to produce real time noise maps. More in details, the system involve cheap sensors capable of anomalous event recognition and cancellation [20][21][22], traffic cluster analysis for mapping optimization [23], web based GIS software for scaling and sum, and for map web presentation. In addition to the above, also a sensitivity analysis of the acoustic calculation model with respect to environmental variables inside and outside urban areas is considered [24].

5. Conclusions

Investigation results have shown that three major approaches to produce real-time noise maps are available at the time being: on-line calculation based on measured data (noise or ‘noise correlate parameter’), scaling and sum of pre-computed maps according to measured data, noise monitoring networks and citizens contributive mapping.

In these terms Dynamap, confirms its peculiarity to achieve cheap and easy to use reliable real-time noise maps, by combining low-cost devices (cheap sensors = many measuring points, no needs of noise mapping software license) with clean measurements (recognition and removal of spurious noise to have reliable measurement data), and a scalable and easy to read result presentation (Realtime Noise maps on a GIS- website). Therefore, the project confirms its compliance with END requirements for both noise maps production and information to citizens.

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THE LIFE DYNAMAP PROJECT: AUTOMATING THE PROCESS FOR PILOT AREAS LOCATION

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In this paper the method applied to identify the sites to be used as pilot areas to demonstrate the feasibility of real time noise mapping within the LIFE DYNAMAP project is described. The project includes the selection of two pilot areas to test the different requirements associated to major roads and agglomerations. In particular, the first pilot area will be located in the city of Milan and will cover a significant portion of the town, including different type of roads and acoustical scenarios. The second pilot area will be located along a major road, i.e. the ring road surrounding the city of Rome. In this case, about one quarter of the ring road, for a total length of 25 km, will be equipped with the Dynamap monitoring sensors. The identification of the pilot areas has been accomplished using a special tool, implemented in a GIS environment, to address the information to be retrieved and support the selection process. The tool takes into account environmental and infrastructural factors, such as noise levels, population density, number of dwellings and people exposed to noise, the presence of additional noise sources, as well as other infrastructural and environmental information, like the availability of further devices (traffic counting sensors, meteorological and air quality stations), communication networks and electric power connections. As final output, the tool has provided two ranking lists, one for the agglomeration of Milan and the other one for the city of Rome, reporting the prioritized sites where the DYNAMAP monitoring system devices will be installed.

1. Introduction

The LIFE DYNAMAP project is a complex five years long project aimed at demonstrating the feasibility of preparing and updating real time noise maps using low cost sensors and a general purpose GIS platform. Scope of the project is the European Directive 2002/49/EC (END) relating to the assessment and management of environmental noise. In particular, the project refers to the need for noise maps to be updated every five years, as stated in the END. Nevertheless, the updating of noise maps using a standard approach is time consuming and costly and has a significant impact on the financial statements of the authorities responsible for providing noise maps, such as road administrations and local or central authorities.

To facilitate the updating of noise maps and reduce their economic impact, noise mapping can be automated by developing an integrated system for data acquisition and processing, able to detect and report in real time the acoustic impact of noise sources. The system will be composed of low-cost sensors measuring the sound pressure levels emitted by the noise sources and of a software tool based on a GIS platform able to perform real-time noise maps.

While this approach seems quite promising in areas where noise sources are well identified, such as those close to main roads, in complex scenarios, such as in agglomerations, further consideration is needed to make the idea feasible.

The project will be accomplished through four main steps:

- Development of low-cost sensors and tools for managing, processing and reporting real-time noise maps on a GIS platform;
- Design and implementation of the DYNAMAP systems in two pilot areas located in the cities of Milan and Rome.
- Systems monitoring for at least one year to check criticalities and analyse problems and faults that might occur over the test period. The test results will then be used to suggest system upgrades and extend implementation to other environmental parameters;
- Provision of a guideline for the design and implementation of real-time noise mapping.

2. Road network analysis and pilot areas location

The implementation of the DYNAMAP system requires the identification of suitable sites to be used as pilot areas for project demonstration activities. Two pilot areas are foreseen to test the different requirements associated to major roads and agglomerations.

The first pilot area is located in the city of Milan and will cover a significant portion of the town, including different type of roads and acoustical scenarios. Roads will be classified and assigned to a suitable number of clusters, on the basis of traffic characteristics. Twenty four roads representative of these clusters will be continuously monitored to provide noise levels for the update of noise maps. Traffic data collected by on site available vehicles counting devices will be integrated in the dynamic noise mapping system to improve and refine noise maps with real traffic information.

The second pilot area is located along a major road, i.e. the ring road (Motorway A90) surrounding the city of Rome. Sensors devices will be installed in hot spots where traffic counting is unavailable to feed the dynamic mapping system with real time information on noise levels. About 25 devices will be used to provide information on noise levels generated by the motorway and dynamically update noise maps. About one quarter of the ring road, for a total length of 25 km, will be equipped with the new sensors.

3. Milan: Pilot Area 1 selection

The selection of the pilot area related to the city of Milan was accomplished using a procedure specifically developed for the project. The procedure was applied to nine territorial areas corresponding to the districts of Milan Municipality (Fig. 1), providing as final output a ranking list showing the scores assigned to such areas as a function of a weighted number of attributes associated to them. The procedure was based on data (georeferenced or not) retrieved from public administrations that were considered useful to the project. All these information were collected into a Geographic Information System (GIS), so as to support and automate the selection process.

3.1 Description of the tool

The procedure to select the pilot area consists of a ranking system based on scores to be assigned to the districts of Milan Municipality. The scores depend on a series of descriptive attributes related to territory and mobility features, noise monitoring systems and air quality/weather stations availability, the criticality of the area in terms of noise levels, the presence of other noise sources and the access to communication channels (Wi-Fi access points). In Table 1 the variables contributing to the calculation of the score are described. The score is automatically assigned using georeferenced data, on the basis of the following criterion:

- a score ranging from 1 (lowest score) to 9 (highest score) is generally given to districts for each variable category as a function of their position on the ranking list, achieved by combining the figures related to the variables included in the category. Depending on the variable category, districts are sorted ascending or descending (Table 1 for sorting criteria);
- a fixed score of 3 points is assigned for each air quality/weather station present in the area; likewise a 6 points score is allocated for each noise monitoring station(see Table 1).

The scores assigned to variables are then weighted using the coefficients depicted in Table 1. The total score of each zone is finally obtained by adding the resulting values. In the end, the ranking list is achieved sorting (descending) the scores associated to the district zones.

Table 1. Variables list, score assignment criteria and weights.

Variable category	Variable	Score assignment criterion	Weight (*c*)
Territory	Area [km^2]	Sort descending	0,25
	Number of citizens [n]		0,50
	Linear road length [km]		0,25
Road traffic	Urban traffic plan (PGTU) class distribution [n]	Sort descending	1,00
	Average daily traffic (ADT) [n]		0,50
Acoustic data	Population exposed to L_{den} > 70 dB(A) [n]	Sort descending	1,00
	Pop. exp. to noise levels > limit for nightime [n]		1,00
	Number of measures (> 24h) [n]		1,00
Noise monitoring	Noise monitoring terminal(NMT) [n]	6 pts/terminal	1,00
Non acoustic data monitoring	Road traffic monitoring stations [n]	Sort descending	1,00
	Air quality/weather stations [n]	3 pts/station	1,00
Other sources	Railway length [km]	Sort ascending	0,50
	Tramway lenght [km]		0,50
Data transmission	OpenWifi access points [n]	Sort descending	1,00

3.2 Data collection and processing

Most of the territorial and mobility data were retrieved from the GIS of Milan Municipality, while information on noise levels were provided by the University of Milan-Bicocca. Both data were georeferenced and available in shapefile format, conversely, some information, like the distribution of open wifi access points were not georeferenced and a manual process was necessary to georeference them, so as to proceed with the calculation automatically. Figure 1 shows graphically the layers used to classify the nine districts. Table 2 contains a brief description of the data related to each layer.

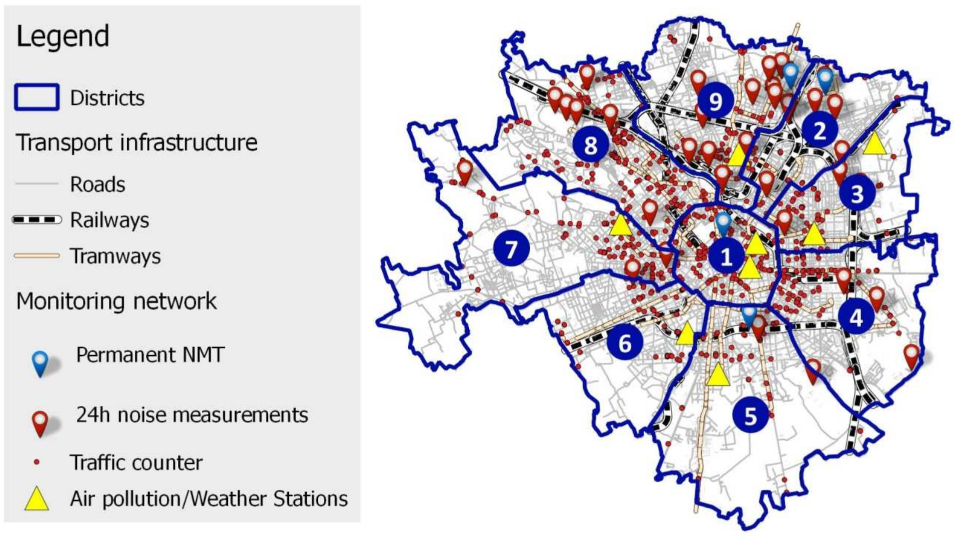


Figure 1. Layers used to characterize the nine districts.

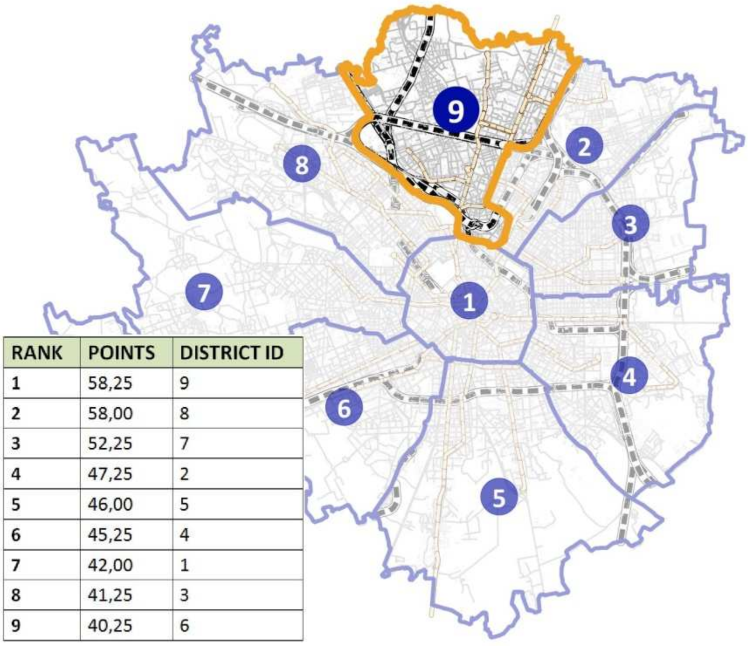
Table 2. Description of retrieved data.

Layer	Description
Road network	Road graph (shapefile). It contains arc distance, mean daily traffic, PGTU class. Road traffic flow data come from AMAT simulation model
Railways	Railway graph used to calculate the length of the network
Tramways	Tramway graph used to calculate the length of the network
Residential Buildings	Polygonal shapefile containing data about population, noise level exposure and limit values. Data come from the strategic noise map of Milan.
Noise Monitoring Stations	Point shapefile containing information on measure type (?) and instrument typology (fixed or temporary noise stations). Data provided by the University of Milan-Bicocca.
Traffic Monitoring Stations	Point shapefile including data on road traffic retrieved from counting devices.
OpenWifi_Access_Points	Text file regarding open wifi access point.

3.3 Ranking list and description of the selected area

In Fig. 2 the ranking list achieved applying the methodology previously described is shown. The table highlights that districts 8 and 9 have reached the highest scores. This was mainly due to the critical situation in terms of noise pollution estimated in these two districts. Figure 2 also shows that Milan district number nine was finally selected as urban pilot area for the Dynamap project. The choice of district 9 was also influenced by the availability of a consistent archive of 24 hours noise measurements and the presence of at least one permanent noise monitoring terminal. These features are of great importance as a thorough knowledge of the acoustic phenomenon in the area under examination is a key element for a successful development of the project.

District nine is located in the north part of Milan and it has a population of about 180.000 citizens. From an acoustic point of view, it was classified as a critical area. The strategic noise map prepared for the second round of END shows that 40.000 citizens are exposed to Lden values higher than 70dB(A). The population of district nine is mostly annoyed by road traffic noise. As a matter of fact this area is characterized by major roads used by commuter traffic from the densely populated northern suburbs of the city. Furthermore, the selected pilot area includes two sensitive sites to be protected from noise as the greatest hospital in Milan (Niguarda) and the university district of Milano-Bicocca.



RANK	POINTS	DISTRICT ID
1	58,25	9
2	58,00	8
3	52,25	7
4	47,25	2
5	46,00	5
6	45,25	4
7	42,00	1
8	41,25	3
9	40,25	6

Figure 2. Pilot area selected as urban test site for the Dynamap project and ranking list.

4. Rome: Pilot Area 2 selection

The pilot area of Rome is located along the ring road (A90 Motorway) surrounding the city. The ring road is a six lanes motorway, 68 km long, skirting many suburban areas where noise levels were found to be critically impacting on the residents. Critical areas are characterized by different scenarios where single or multiple noise sources are present, such as railways, crossing and parallel roads. As a consequence, the overall noise level depends on the number and contribution of the sources existing in the area. As the Environmental Noise Directive states that only the primary source should be mapped, the contribution of the other sources must be eliminated or at least dramatically reduced. To that end, suitable sites should be identified to place the sensors, so as to contain the influence of the other sources as much as possible. However, in order to check the feasibility of deleting the contribution of other noise sources, including temporary spurious events, with the ANED algorithm, more complex scenarios have been foreseen to be part of the selected test sites. For this reason, it seemed reasonable to provide four different type of test sites, representative of the main suburban scenarios:

A. **single road**: this category includes areas with the mere presence of the primary source (A90 Motorway)
B. **additional crossing or parallel roads**: this category includes areas with other crossing or parallel roads belonging to ANAS
C. **railway lines running parallel or crossing the A90 motorway**: to this category belong those sites where railways are running parallel or crossing the A90 motorway
D. **a complex scenario including multiple connections**: this category refers to suburban scenarios where many connections to other roads are present, including the contemporary presence of additional noise sources, such as railways

Pilot area 2 will be composed of many test sites, distributed along the motorway A90. The final number of sites will be defined on the basis of the amount of sensors necessary to calibrate and update the maps. A maximum of 25 sensors was foreseen to be installed.

To select the sites where the DYNAMAP sensors will be placed, a GIS tool was accomplished to collect and process information related to the 67 critical areas identified by ANAS Action Plan in the first and second round of the END.

4.1 Description of the tool

A specific tool was developed for the pilot area of Rome taking into account the information available from ANAS data base and the Action Plan accomplished for the first and second cycle of END. The tool provides for the creation of four ranking lists of critical areas, retrieved from those identified in the Action Plan, corresponding to the suburban scenarios A to D. The ranking lists were based on a priority index associated to the critical areas, that takes into account the following information:

- noise levels;
- population density;
- number of dwellings and amount of people exposed to noise.

For the selection process of the test sites, other information were necessary, such as the presence of additional noise sources, as well as other infrastructural and environmental information, like the availability of further devices, communication networks and electric power connections. The tool was implemented in a GIS environment, through an algorithm based on the following five steps:

Step 1: identification of critical areas along the A90 motorway within a buffer 500 m wide;
Step 2: filtering of critical areas missing connection to the power grid and communication channels;
Step 3: selection of critical areas with traffic counting devices;
Step 4: identification of critical areas with additional noise sources;
Step 5: sites classification.

In Table 3 the description of the layers used as input in the GIS tool is shown.

Table 3. Description of layers.

Layer	Description
Road Network	Road graph. It contains the arcs belonging to the A90 motorway
Other Roads (ASA)	Road graph. It contains the arcs related to roads belonging to ANAS running parallel or crossing the A90 motorway within a buffer 250 m wide each side of the motorway axis.
Railways (FS)	Graph of the railways running parallel or crossing the A90 motorway within a buffer 250 m wide each side of the motorway axis, identified and included in the Action Plan.
Critical Areas (CA)	It contains the areas where noise limits values are exceeded, retrieved from ANAS Action Plan.
Variable Message Panels (PMV)	Point layer reporting information on the location of Variable Message Panels.
Traffic Counting Devices (TC)	Point layer related to the position were traffic monitoring devices are installed.
Switchboard (PMV_quadri)	Point layer reporting information on the position of the switchboards along the motorway.

4.2 Data collection and processing

For the selection of the sites related to the second Pilot Area, sixty-seven critical areas, located along the motorway A90 were taken into account. The critical areas were identified on the basis of the results achieved from ANAS noise mapping and action planning activities, accomplished in 2013 for the first and second cycle of END, in compliance with National and European legislation.

Data related to such critical areas were used to feed the GIS tool and provide as output a ranking lists of sites suitable to the installation of the DYNAMAP system.

For each critical area the following information were available from the Action Plan:

- receivers type;
- receivers distance from the road;
- geometrical features of receivers buildings (area, volume, numbers of floors, exposed facade, etc.);
- noise levels at receivers and related national limits;
- noise exceeding levels;
- road name, type, geometrical features and location;
- road pavement type (standard or low noise surface);
- traffic volume, composition and speed;
- priority index;
- existing noise mitigation measures;
- noise mitigation measures to be implemented in the forthcoming years.

The proper installation of the devices on the test sites requires, however, further information, such as those related to the availability of power grid connections and communication networks, traffic counting systems and other noise sources that could influence the overall noise level.

The complete input layers were then used to feed the DYNAMAP tool, whose output resulted in four lists complying with the requirements related to the main suburban scenarios.

4.3 Ranking list and description of selected area

The tool provided as output four ranking lists of critical areas, for a total of seventeen test sites, complying with the requirements related to the main suburban scenarios, as described at the beginning of paragraph 4, sorted by their priority index, as follows:

A. **Single road:** this list includes twelve areas, in order of decreasing priority, characterized by the sole presence of the primary source;
B. **additional crossing or parallel roads:** this list includes only one critical area with other crossing or parallel roads belonging to ANAS;
C. **railway lines running parallel or crossing the A90 motorway:** this lists reports two sites where railways are running parallel or crossing the A90 motorway;
D. **a complex scenario including multiple connections:** this lists refers to suburban scenarios where many connections to other roads are present, including the contemporary presence of additional noise sources, such as railways. Two critical areas were identified for this list.

5. Conclusions

In this paper the methods used and the results achieved are described. Two pilot areas were foreseen in the project. The first pilot area, representative of an urban scenario, is located in the agglomeration of Milan, while the second one, representative of the main suburban scenarios, is placed along the A90 motorway that surrounds the city of Rome. For the selection of the pilot areas a GIS tool was developed in order to standardize the selection process and ease data collection.

As for the first pilot area, the tool required also the definition of an index to be assigned to the nine districts in which the city was split, taking into account a series of parameters, that were judged to be of interest for the identification of the test site. The selection process provided a ranking list from which district nine emerged as the most suitable area to host the DYNAMAP system.

A different approach was required for the pilot area located in Rome, where many test sites placed along the A90 motorway are foreseen. Also in this case, the identification of the test sites was based on the availability of weather and air quality monitoring stations, traffic counting devices, electric grid and communication connections, but most of all on the presence of hot spots where noise limits values are exceeded. The tool developed in this case, provided four ranking lists representative of the main acoustic scenarios:

A. single road (A90 Motorway);
B. additional crossing or parallel roads;
C. railway lines running parallel or crossing A90 motorway;
D. a complex scenario including multiple connections.

A total of seventeen sites complying with these specifications were found.

Acknowledgements

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DYNAMAP: SENSITIVITY ANALYSIS OF THE ACOUSTIC CALCULATION MODEL WITH RESPECT TO ENVIRONMENTAL VARIABLES INSIDE AND OUTSIDE URBAN AREAS

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Within the DYNAMAP project, which aims to produce a dynamic noise map in different physical context, it is useful to preliminarily define the sensitivity of the acoustic model, with respect to some environmental variables. Starting with an analysis of the relevance of noise attenuation factors, function of the distance and the type of sources, it was decided to explore the sensitivity of the acoustic model with respect to weather conditions, in suburban context, and vehicular traffic flow conditions, in urban context. The noise calculation algorithm adopted is XPS 31-133/NMPB.
The sensitivity of the model with respect to the occurrence of favourable or homogeneous weather conditions, has been assessed through repeated simulations in which only weather conditions vary. The refraction of sound rays in the atmosphere layers (favourable conditions) results in a greater persistence of the sound wave near the ground and therefore in a greater interaction with it. Hence the characteristics of land cover appear to be a discriminating factor to evaluate the influence of weather conditions on noise propagation. Several scenarios have been simulated calculating noise levels at an array of receptors with varying weather conditions, ground type and relative source-receiver height. Source conditions were instead kept constant. The results can guide the acquisition of local weather information required in the simulation process according to the different weather conditions settings.
In urban areas instead, traffic flow conditions have a direct influence on the sound power of the road source. Through different scenarios, the relationship between sound power of road source is then calculated in function of: type of flow (continuous, accelerated, decelerated and interrupted), percentage of heavy vehicles, average speed. Some possible approaches to modelling of traffic conditions in urban context are here proposed and evaluated.

1. Introduction

DYNAMAP is a LIFE+ five year project aimed at demonstrating the feasibility of real time noise mapping.

The updating of noise maps can be automated by developing an integrated system for data acquisition and processing, able to detect and report in real time the acoustic impact of noise sources. Only road traffic sources will be investigated. The system will be composed of low-cost sensors network measuring the sound pressure levels emitted by the noise sources and of a software tool based on a GIS platform able to perform real-time noise maps.

Design and implementation of the DYNAMAP system will be accomplished in two pilot areas located in the city of Milan and in the surroundings of Rome.

A model of each pilot area will be implemented in an acoustic calculation software and will be the base for the surface noise maps production. Baseline noise maps are updated in real time as a function of local noise levels acquired from source oriented low cost stations. Some parameters of the calculation model will be changed according to significant variations of the environmental conditions; thereby a new baseline map, independent from acquired acoustic data variation, has to be produced.

The baseline acoustic model will be performed using XPS 31-133/NMPB algorithm, which includes both the road sound power computation in function of traffic input data, and the calculation of the environmental noise attenuation along each source-receiver propagation path.

The implementation of Dynamap system in two different environmental contexts requires the identification of the most significant and relevant parameters to be analyzed: meteorological conditions in extra-urban areas; traffic conditions in urban areas.

In this paper the sensitivity of the adopted acoustic model is analyzed with respect to these two variables, that is considering how the values of the terms "weather conditions" and "traffic conditions" influence the environmental noise level or the noise level emitted by the source.

2. Sensitivity analysis with respect to meteorological conditions

XPS 31-133 algorithm takes into account the occurrence of homogeneous or favourable to propagation weather conditions. At a physical level, weather conditions that influence noise propagation are related to the wind speed and temperature vertical gradients. When a fixed threshold is reached, sound ray is refracted downward causing the enlargement of the affected area.

Sound ray refraction induced by atmosphere layers determines a longer persistence of the sound wave at the ground level. The effects of the terrain on the noise propagation path are therefore increased. Interferences between sound wave and terrain, identified as reflection and absorption, are also related to the source height with respect to the receiver height. Consequently, the height of the source, that is the roadway, relative to the ground level, modifies the effects and the dimension of the weather conditions influence field. This is due to the combined effects of reflection, absorption, diffraction and interference.

In long term noise levels calculation, as required by END 49/2002, weather conditions influence is determined from the weighted energetic average of the favourable and homogeneous (not favourable to propagation) yearly average levels. The effect on the long term period of favourable conditions is expressed as an occurrence factor (in percentage) calculated from a statistical analysis of meteorological data. These can be measured or evaluated according to general principles and refer to each angular sector of the noise field. In the study case the favourable conditions calculation has been done with an occurrence factor of 100%.

In order to evaluate the model sensitivity with respect to favourable or homogeneous weather conditions, specific calculations have been carried out keeping other parameters fixed and varying just those related to meteorological conditions and other factors directly connected with them.

Source parameters (single line source, road geometrical parameters, traffic flow and traffic composition) as well as calculation settings have been kept fixed. Some series of calculations have been done implementing XPS 31-133 algorithm in *CadnaA* noise modelling software with the following settings.

Constant parameters:

- Noise source: grade-level road, 10 km length, Lw'=100,3 dB(A).
- Calculation parameters: search ray distance, maximum reflection order.
- Array of 50 receivers, spaced 10 meters apart, from 10 to 500 m distance; receiver height: 4 meters.

Variables:

- Road height (H): ground level, road embankment 2m, 4m, 6m, 8m, 10m.
- Ground factor (G): 0,0 - 0,2 - 0,4 - 0,6 - 0,8 - 1,0.
- Meteorology: favourable/homogeneous conditions.

Source-receiver relative height varies from -4 to +6 m.

In total 72 runs have been carried out. In the following graphs (Figs. 1-3) some results are presented as difference between noise levels in favourable and homogeneous conditions. In the x-axis the source-receiver distance is shown. Graph curves represent the trend lines calculated as a three-element moving average.

It can be noticed how an increase of noise levels occurs in favourable weather conditions; it becomes significant starting from noise paths greater than 100 meters. This effect is greatly amplified in presence of absorbing soils and low elevation level road sources.

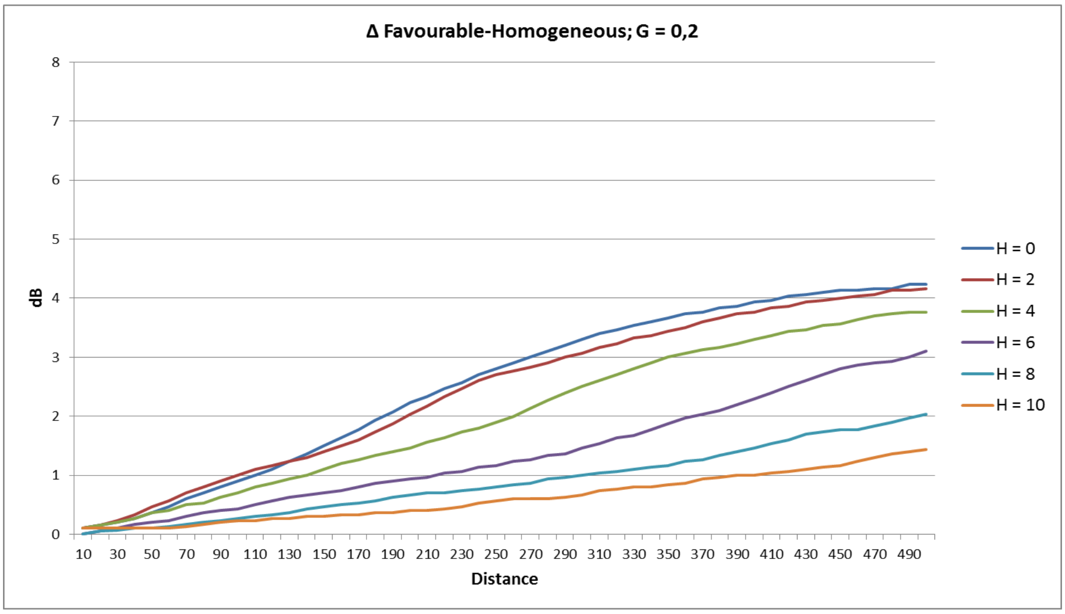


Figure 1. Differences between favourable and homogeneous conditions calculated noise levels. Ground Factor = 0,2

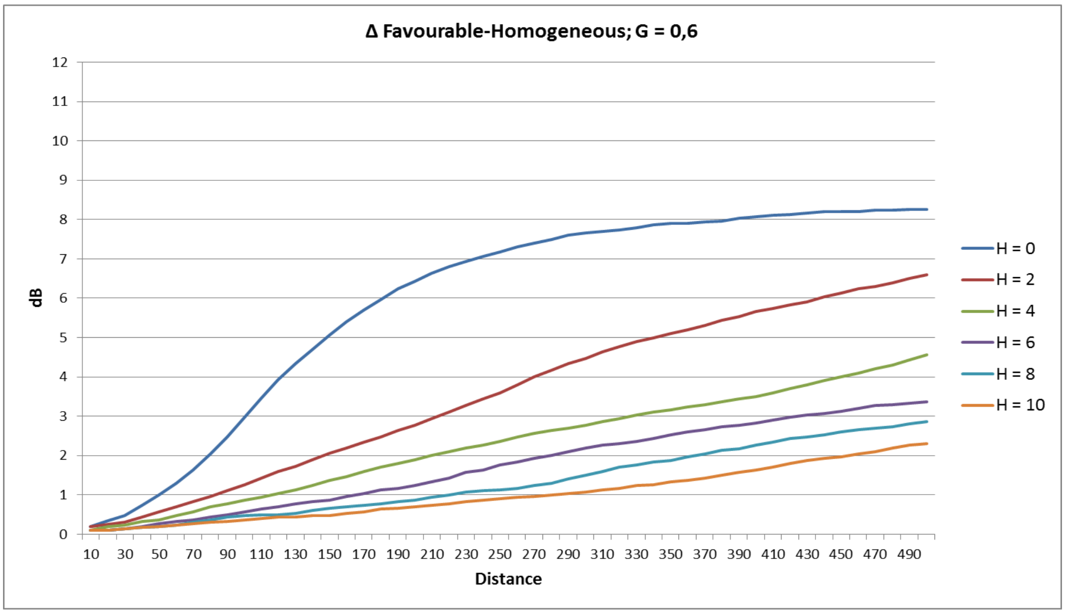


Figure 2. Differences between favourable and homogeneous conditions calculated noise levels. Ground Factor = 0,6

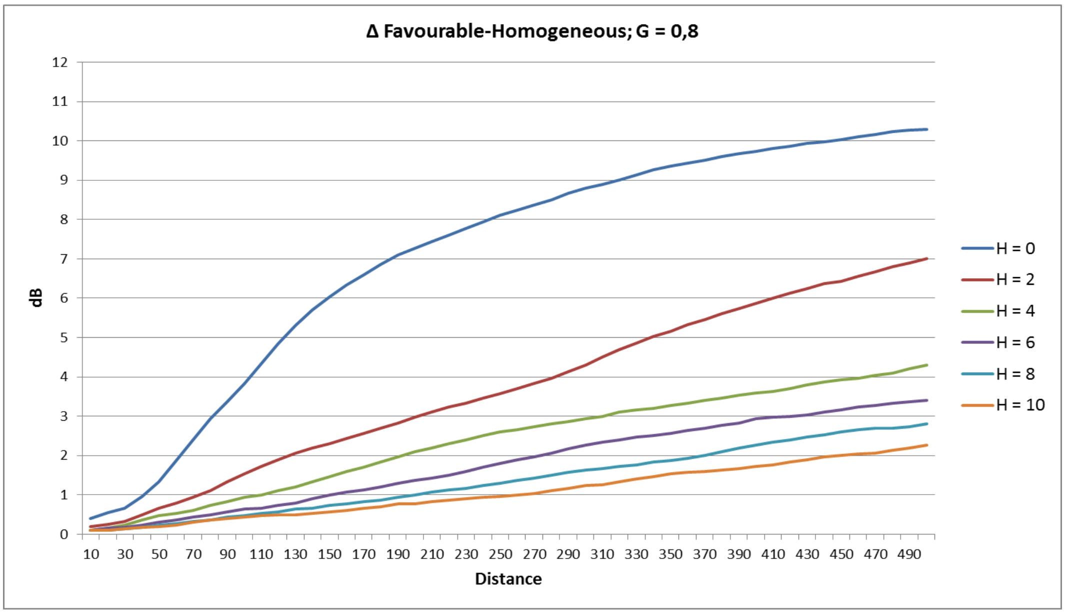


Figure 3. Differences between favourable and homogeneous conditions calculated noise levels. Ground Factor = 0,8

3. Sensitivity analysis with respect to traffic conditions

In typical urban areas, traffic conditions vary significantly with respect to the presence of connections, junctions, traffic lights and to the length of the road stretches. The temporal variability of flow conditions depends on short-time effects (traffic light duration) and on long-time effects, such as peak or low traffic periods. According to the XPS 31-133 method, these traffic conditions directly influence the computation of sound power emitted by a single road segment. The algorithm considers four flow conditions: continuous, accelerated, decelerated and interrupted. Other variables related to the traffic conditions and strictly connected to the estimated sound emission are: percentage of heavy vehicles, average speed.

Computations are carried out considering six percentage classes of heavy vehicles (from 0% to 5%; step 1%). For each of them, the relationship between LAw' (linear sound power level) and the variable average speed (five classes from 30 km/h to 50 km/h, step 5 km/h) was assessed considering the four traffic flow conditions.

Overall, 120 calculations of the noise emission level of the road source were performed.

The examined average speed and percentage of heavy vehicles ranges are typical of Milan urban traffic. The parameter "traffic flow conditions" results to be the most relevant in the calculation of emission levels; the effect of this parameter, in general, decreases with increasing average speed.

In the following graphs (Figs. 4-5), as an example, estimated sound power levels are presented in relation to the vehicles speed. The other parameters in the computation of sound power absolute values have been kept fixed (traffic flow = 1000 veh/h).

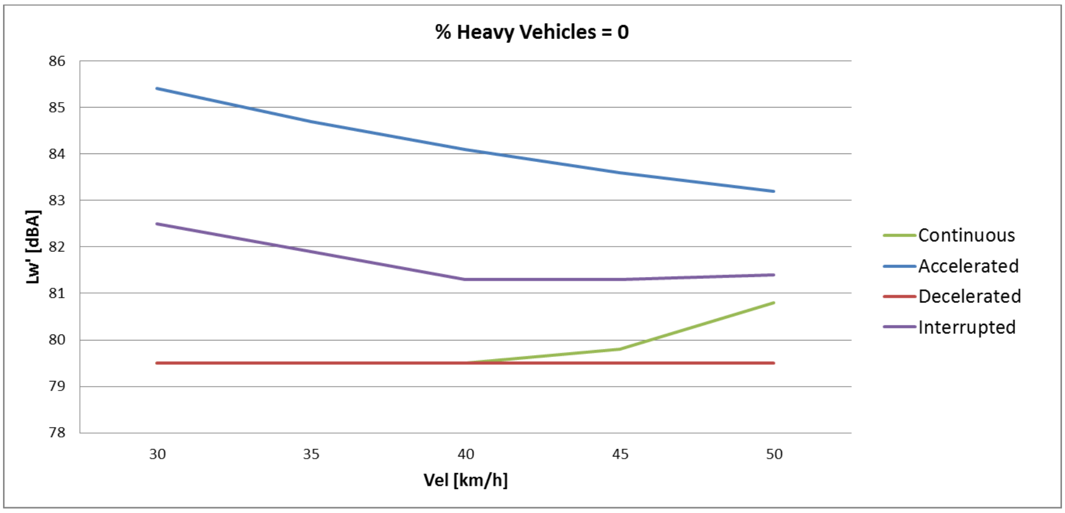


Figure 4. Calculated sound power levels in different traffic flow conditions. Heavy vehicles = 0%

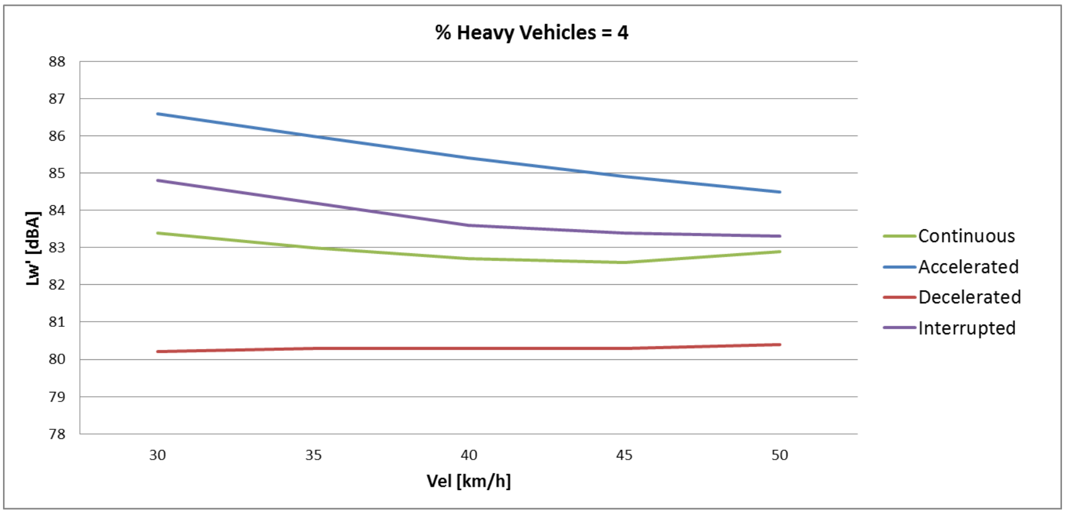


Figure 5. Calculated sound power levels in different traffic flow conditions. Heavy vehicles = 4%

As it can be noticed from the comparison between Fig. 4 and Fig. 5, high percentages of heavy vehicles determine higher sound power levels -even in case of continuous traffic flow conditions- which increase as the speed values decrease (see the green line relative to speed values lower than 45 km/h).

3.1 Urban traffic flow conditions: two simulation approaches

Two different approaches for the simulation of the vehicular traffic, as representative examples, are proposed here. In the first approach flow conditions are assumed to be “continuous” in each road segment and the speed value is consistent with the urban speed limit. In the second one they are assumed to be “interrupted” nearby a crossroad and the speed value is 30 km/h; these settings are applied to the 100 meter long road segments starting from the center of the intersection. Interrupted condition results to be an average between accelerated and decelerated conditions, so it smoothes the differences in case of track roads flows.

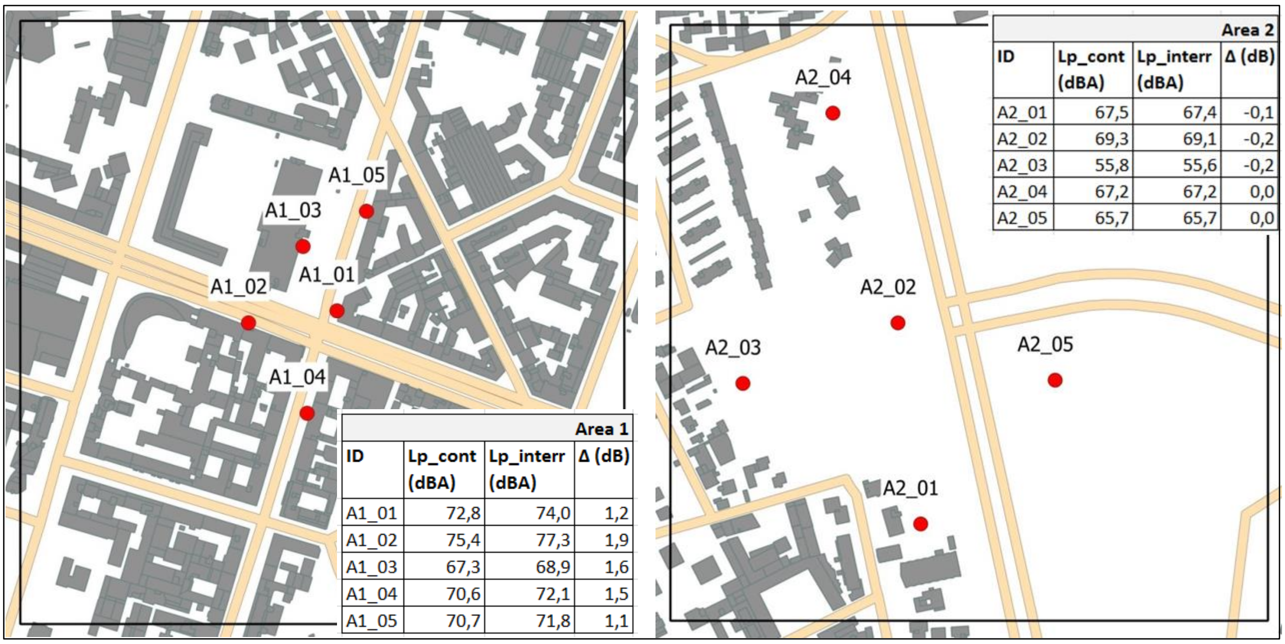
The effects of the two different simulation techniques are studied on two areas that show differences in terms of building density and road category (see Fig. 6):

- Area 1: high density urban area, vehicles’ speed of 50 km/h in average conditions.
- Area 2: suburban area, low building density, vehicles’ speed of 70 km/h in average conditions.

Each area is then modelled following the two approaches suggested.

The differences in sound pressure levels (*Lp_interr*, for the “interrupted” traffic flow – *LP_cont*, for the “continuous” traffic flow), calculated at 5 points for each area, allow to evaluate the effects of the different settings, as shown in the results tables inside Fig. 6.

Significant differences (>1,0 dB) are found exclusively in Area 1 which is characterized by high building density and traffic speed values typical of local roads (50 km/h). On the contrary, on high flow roads (Area 2) we can observe how changes from continuous to interrupted traffic conditions don’t determine relevant differences in the sound pressure levels estimated.



Area 1			
ID	Lp_cont (dBA)	Lp_interr (dBA)	Δ (dB)
A1_01	72,8	74,0	1,2
A1_02	75,4	77,3	1,9
A1_03	67,3	68,9	1,6
A1_04	70,6	72,1	1,5
A1_05	70,7	71,8	1,1

Area 2			
ID	Lp_cont (dBA)	Lp_interr (dBA)	Δ (dB)
A2_01	67,5	67,4	-0,1
A2_02	69,3	69,1	-0,2
A2_03	55,8	55,6	-0,2
A2_04	67,2	67,2	0,0
A2_05	65,7	65,7	0,0

Figure 6. Urban context scenario simulations

4. Conclusions

Some useful considerations may arise from the results of the sensitivity analysis of the acoustic model.

The calculation of the year noise maps (as required by 49/2002 END) is also affected by the meteorological conditions, in particular by the percentage occurrence of favourable to propagation conditions compared to homogeneous conditions. To produce noise maps which are dynamically calculated relatively to a short period of time (at the longest one hour), as a purpose of Dynamap project, the availability of historical or measured meteorological data of the investigated area permits to obtain different baseline noise maps according to different meteorological conditions. The model performer, according to the available data set or to weather data acquisition mode, can arrange such baseline maps with a daily or seasonal time variation.

In relation to the different traffic conditions that occur in the urban area, the results of two scenario simulations have been here presented. The first one reproducing continuous flow conditions on all the road segments; the second one reproducing variable conditions with interrupted flow at the junctions and continuous flow on the straight sections. Also in this case, the results obtained can guide the drawing of different baseline maps of the urban environment, which take into account the occurrence of interrupted flow conditions during certain times of day, for example in presence of traffic congestion, slowdown or rush periods.

Acknowledgement

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TRAFFIC NOISE MONITORING IN THE CITY OF MILAN: CONSTRUCTION OF A REPRESENTATIVE STATISTICAL COLLECTION OF ACOUSTIC TRENDS

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In the context of the European project DYNAMAP, a campaign of acoustic monitoring of road traffic noise was realized in the entire area of the city of Milan.
The operations involve the collection of temporal trends of noise levels in order to create a statistically significant sample for post-processing analysis.
The monitoring activities encompass the following steps:
- collection and selection of previous noise data concerning the road sources;
- identification and selection of monitoring sites based on specific criteria such as road geometric characteristics, the functional road classification (A, D, E, F), the type of traffic, the absence of other noise sources, etc.;
- acquisition of the acoustic data by weekday using various types of units for the long-term noise monitoring;
- correlation of acoustic data with weather data and deletion of data when levels of rainfall and wind speed exceeding threshold values;
- identification and removal of abnormal events through sonogram analysis;
- acquisition of series of equivalent sound levels, measured on different time intervals: 5, 10, 15, 20, 30 and 60 minutes;
- acquisition of traffic flow data related to road stretches, via statistical modeling or on-site measurements.

All acquired data are stored in a geodatabase useful for further processing, such as cluster analysis and the development of an acoustic model for the city of Milan. The acquisition of noise data will also provide useful indications to size a monitoring network of low-cost sensors, one of the main target of the DYNAMAP project.

1. Introduction

The DYNAMAP project aims at developing a prototype system in an effort to achieve the real-time noise mapping of road infrastructures in two pilot areas: a part of the agglomeration of Milan and a section of the Motorway A 90 in Rome. One of the main goals of the project is to create a low-cost sensor network able to make the five-year update of the strategic noise maps required by the European Directive 2002/49/EC more efficient and less expensive. In further stages of the project a statistical method will be introduced to automate the process of noise mapping.

This paper describes the methodology used to create the initial collection of noise trend required for the statistical analysis of the project.

The original assumption of the project is that an experimental approach, based on real-time noise measurements, could be used to map road's sources in urban areas.

The use of low-cost sensors allows to roll-out a large monitoring network and steadily obtain continuous noise data for long periods of time. This feature introduces a different role for the experimental measurements in the noise mapping process.

Nowadays noise measurements are used mainly to validate results obtained from computational models and they are usually not directly involved into the noise mapping process.

Recent studies, concerning the road noise sources in Milan, revealed that the city's streets show an "acoustic behavior" not strictly related to the road functional categories (A, D, E, F), to the road geometric-structural characteristics (number and width of lanes, the road surface types, etc.) or to their traffic volumes. Therefore it's actually possible identify a limited number of road's clusters characterized by similar noise trends.

The construction of a database, containing the noise emission of road infrastructure obtained in previous measurements and in new measurements in the city of Milan, is necessary to characterize the "acoustic behavior" of homogeneous groups of roads.

Therefore one of the first actions of the project is the realization of a large-scale noise monitoring survey specifically made to improve the previous noise data acquired with new ones.

To this end, a wide traffic noise monitoring campaign was planned on the entire area of the city of Milan, considering the space-time variability of the noise emissions generated by traffic sources. For each measurement point, different series of equivalent noise levels with different time resolutions were obtained for the period of 24 hours.

This study summarizes the first results of this activity which is still ongoing.

2. Collection of previous acoustic data

The first activity involved the archiving of previous noise measurements. From all the historical data available, only those specifically related to road sources and with a duration of 24 hours were selected.

The Department of Environment and Territory and Earth Sciences has carried out since 2007 several measures of acoustic monitoring in the city of Milan.

The collected data have different origins. Some sound level measurements were performed for research purposes, others for collaborative activities carried out for institutions such as the Lombardy Region, the Municipality of Milan and the Milan Territory Environment Agency Mobility AMAT.

The dataset of previous continuous noise monitoring consists in 49 sites, related to 8 different road categories.

The increase of the historical database with noise trends coming from other institutions or research organizations is one of the next targets of the research team group.

3. Execution of acoustic monitoring campaign

The second phase of the study involved the planning and execution of a new campaign of acoustic monitoring, closely related to the purposes of the project DYNAMAP.

In order to create a representative statistical sample of the entire road network of the city, the following general criteria were adopted to identify the measuring sites:

- homogeneous distribution on the entire metropolitan area and between the nine city's districts of Milan;
- uniform distribution between the different road categories (A, D, E, F) and road subclasses (E1, E2, F0, F1; F2, F3);
- various urban scenarios (urban canyons with different conformation, open sound field, etc.);
- different road surface type;
- different traffic flow types (fluid continuous flow, pulsed continuous flow, pulsed accelerated flow or pulsed decelerated flow);
- no influence of other roads on the monitored road stretch;
- absence of other noise sources (tram lines, railways, airports, etc).

In the monitoring campaign, three different types of monitoring units have been used. These units are:

- fixed monitoring stations (Fig. 1 A);
- semi-permanent monitoring stations (Fig. 1 B-C);
- monitoring stations placed on cart or on mobile laboratory (Fig. 1 D-E).

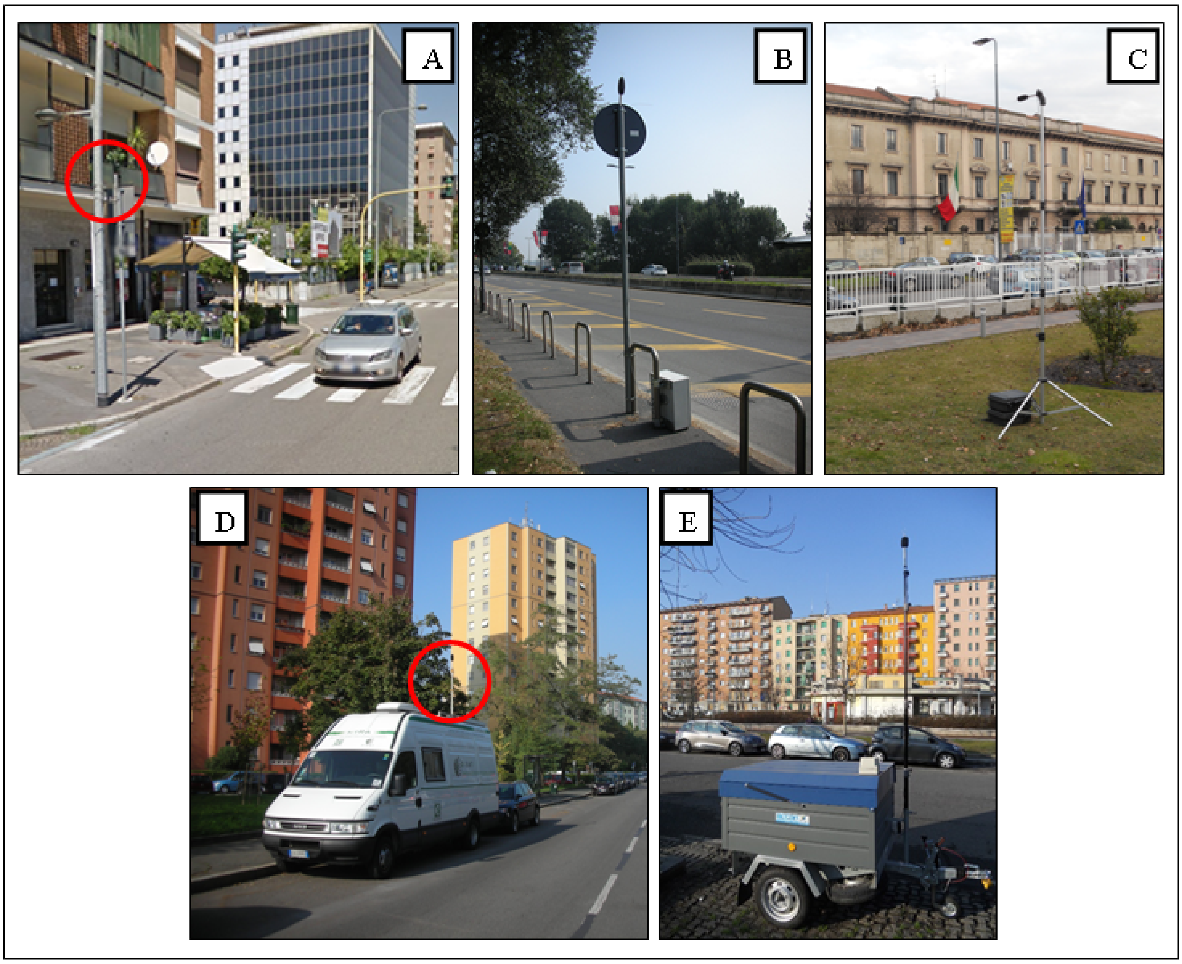

Figure 1. The monitoring stations used during the DYNAMAP noise monitoring campaign.

All monitoring stations are equipped with a class 1 sound level meter able to obtain the main noise indexes and the spectral trends in third-octave bands with a temporal resolution of 1 second.

The monitoring activity was sized on a minimum measurement time of 24 hours, starting at 6 a.m. and eventually protracted for different days.

4. Processing of the measurements

Subsequently to the execution of the noise measurements, all acquired data was elaborated in a three steps.

The first operation involved the exclusion of noise records of public holidays and anomalous days (such as days of school closures) in order to extrapolate only the acoustic data relative to a typical weekday.

The second operation involved the correction of the acoustic data with weather data. The units of acoustic monitoring in fact are not equipped with weather stations, therefore, it was necessary to associate every single noise level with weather data of rainfall and wind speed measured in the different weather stations of ARPA (Regional Agency for Environmental Protection) located on Municipality of Milan (Fig. 2).

To get weather data related to the real weather conditions detectable near each measurement site, each site was selected and compared to the reference weather station closest to the point of measurement itself.

The effect on the acoustic data of rainfall events was evaluated considering a method proposed by ARPA. In detail, the criteria used are:

- precipitation < 2 mm: irrelevant;
- precipitation > 2 mm: influential on individual hourly data;
- precipitation > 4 mm: influential for the time immediately following the event weather.

To evaluate the influence of atmospheric turbulence on the acoustic data, the criterion used is indicated by Italian normative. The acoustic data were discarded when:

- wind speed > 5 m / sec

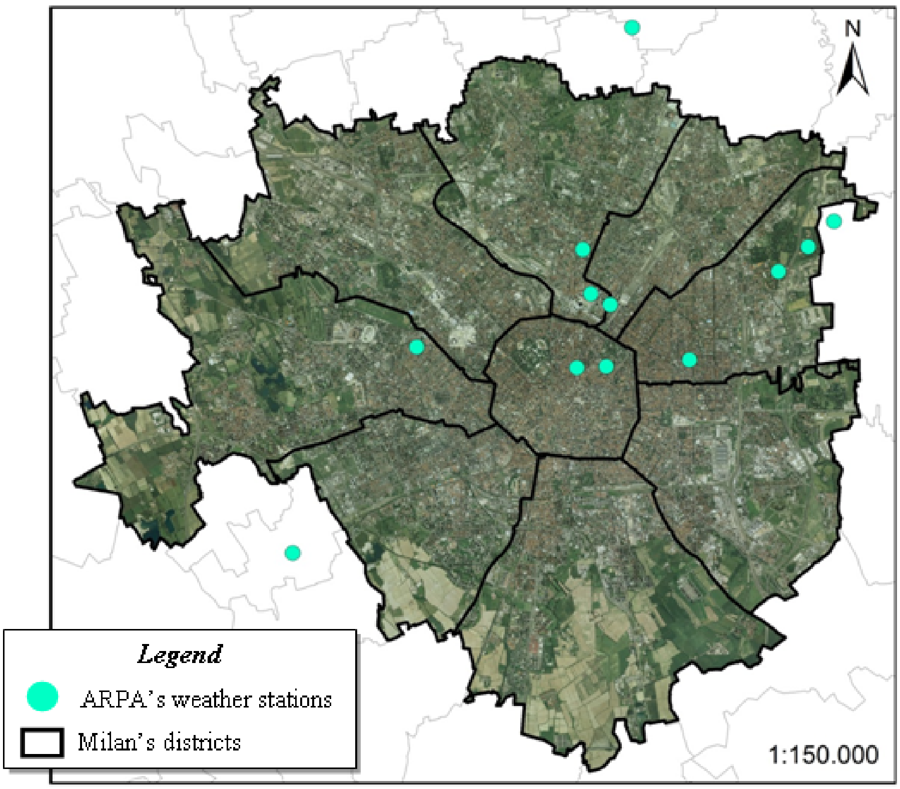

Figure 2. The dislocation of ARPA's weather stations in the territory of Milan.

The third corrective operation of the original acoustic data involved the elimination of extraordinary or abnormal events (such as sirens, horns, airplane transits, noisy human activities, technical facilities, etc.), since their presence can affect and alter the equivalent noise level.

This operation is important because it allows to achieve an acoustic data closely related to the single traffic source.

The identification of the extraordinary events was based on the comparison and analysis of the sonograms. Sonograms are graphic representations of a sequence of spectra in time, where the sound pressure level, in a chromatic scale, is expressed in function of time and frequency (Fig. 3).

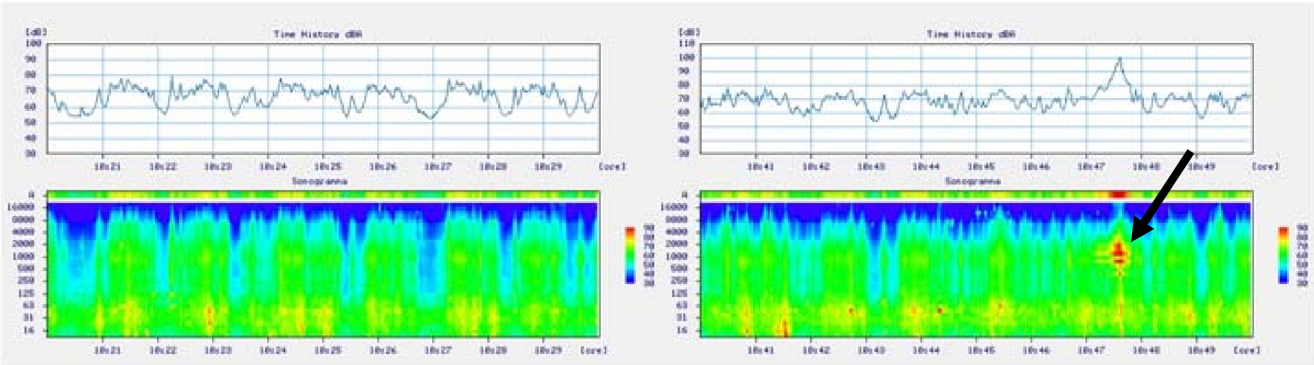

Figure 3. Sonograms related to road traffic in normal conditions and in the presence of an anomalous event (ambulance siren).

After the corrections of the acquired data, the sound pressure levels were calculating by integrating the acoustic data on different time intervals, respectively 5, 10, 15, 20, 30 and 60 minutes.

The succession of equivalent noise levels on 24 hours represents the trend noise, which constitutes the basis for subsequent statistical analysis. Each noise dataset consists of 6 distinct temporal profiles obtained with different sampling of data per second.

At the present state of art, a total amount of 182 noise trends was obtained: 152 coming from previous noise monitoring activities and 50 coming from the DYNAMAP noise monitoring campaign (Fig. 4). These 182 trends well describes the noise emissions of 76 roads of Milan (Table 1). Road categories A and D have been almost entirely described, while the E and F road classes, that show an high internal variability, will be the object of future noise surveys (Fig. 5).

Table 1. The results of the noise monitoring campaigns.

Functional class of road	Number of roads monitored	Number of daily noise trends collected
A	3	5
D	9	20
E1	17	52
E2	10	25
F0	11	19
F1	6	10
F2	9	21
F3	11	30

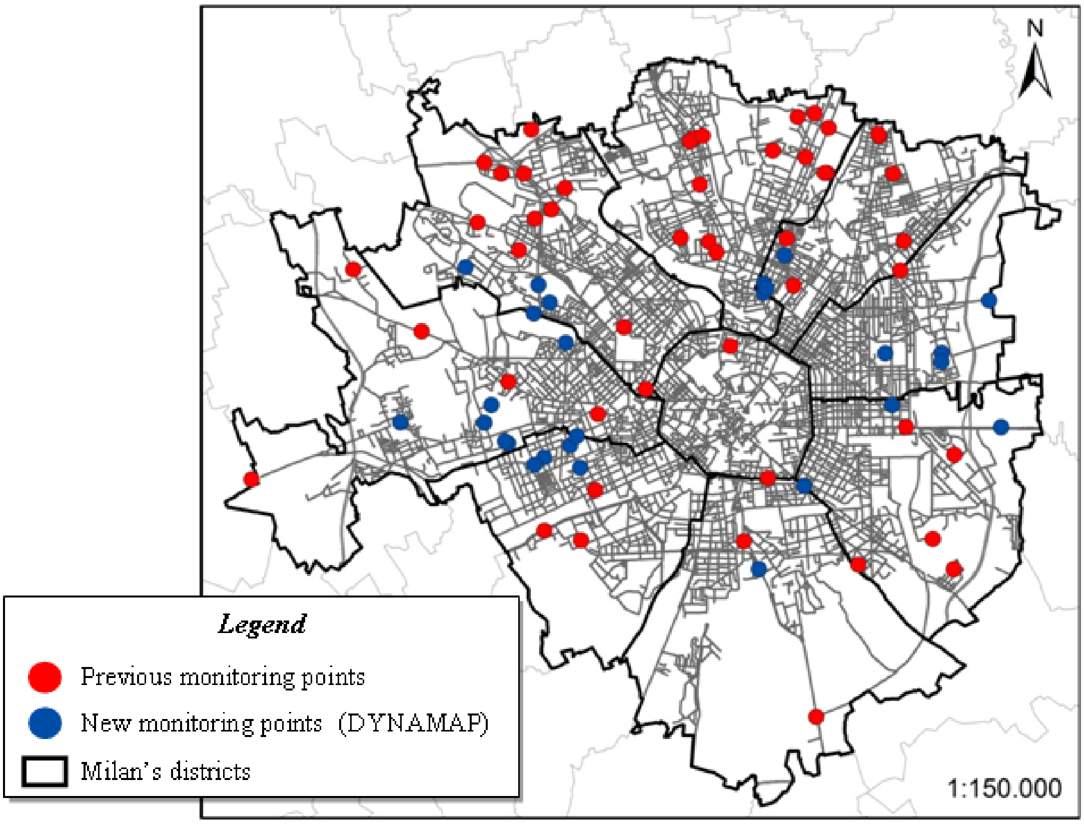

Figure 4. The location of noise measurements positions.

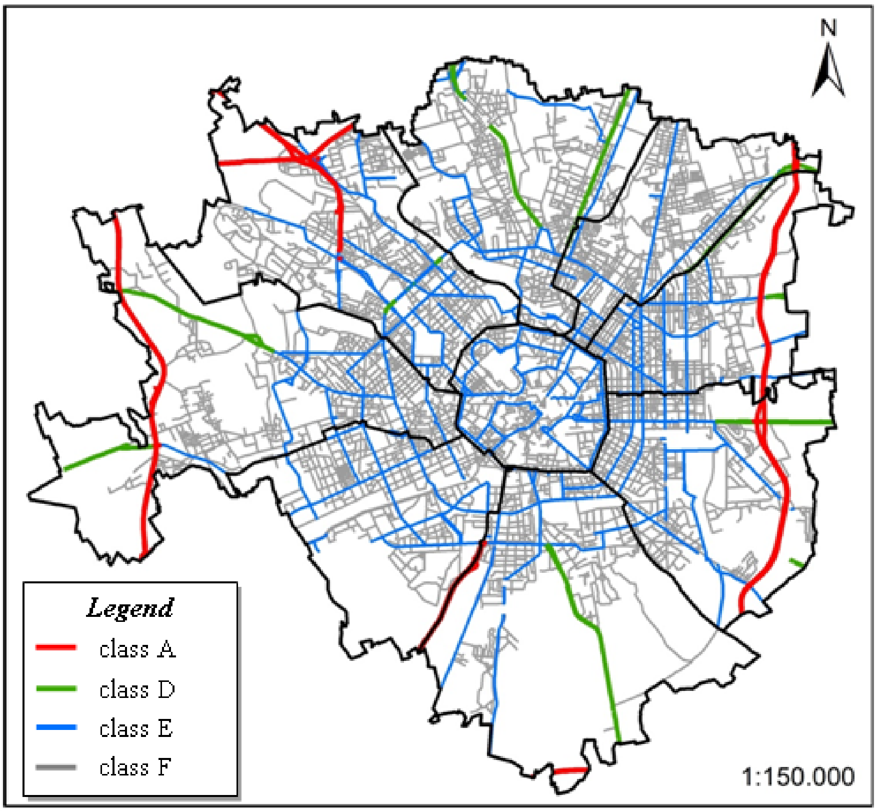

Figure 5. The road's categories of Milan.

5. Traffic flows

The opportunity of applying a statistical method (as provided by the project DYNAMAP) for the description of the entire urban road network requires that, in addition to the acoustic information relating to a road stretches, a "non acoustic" parameter is found to complete the description of all edges of the road network.

The parameter most easily obtainable and directly comparable with the acoustic data is the daily vehicular traffic, expressed in number of vehicles/h and referred to each stretch of the road network.

The data traffic flows can be obtained using two approaches:
- modeling approach, based on origin-destination matrices;
- experimental approach consisting in on-site measurements.

The modeling approach estimates the rate of traffic flow using a statistical model of calculation made for specific mobility's studies by AMAT (Agency of mobility, environment and territory of Milan). The data provided by this model has the advantage of being extended to all road stretches, but on the other hand the data extrapolated are affected by the confidence limits connected to the modeling approach.

The experimental approach is instead performed simultaneously with the campaign of acoustic monitoring and proceeds with the count of vehicular traffic flow through radar instruments, portable traffic analyzers or magnetic loops.

When possible, in addition to the numerical data of traffic flow (vehicles/h), more information were acquired about the traffic composition (number of light and heavy vehicles) and the average speed achieved.

A future phase will analyze the correlations between:
- acoustic data and traffic flow data;
- traffic flow data estimated by the simulation model and those obtained experimentally in situ for test the reliability of the model.

6. Production of a Geodatabase

All data presented were collected on a GIS platform and inserted into a relational geodatabase (DBMS) purposely created. This tool, containing the acoustic data, the data of traffic flows and the georeferenced position of the measuring points, also collects and integrates a large series of information that may be useful for further consideration and elaboration. In detail, these informations are specifically:
- the identification code of the measurement;
- the type of monitoring units used;
- the date and the duration of the measure;
- characteristics of the measurement stations (microphone height, reflective surfaces and obstacles, the distance between the noise source and the roadway edge);
- information about the road monitored such as identification code, name and functional class of the road;
- photographic documentation;
- presence of structures (schools, hospitals, rest homes, etc.) in the neighborhood.

7. Conclusions

This paper briefly explains the various activities that have allowed the creation of the noise data collection, that will be used in the next stages of the DYNAMAP project.

The geodatabase obtained is currently the largest collection of acoustic trend referred to the road network of the city of Milan and it's an important basis for any future processing.

Specifically, in the context of the DYNAMAP project, the collection of data will be the basis for the statistical analysis of the road network in Milan and will represent a useful tool for the future sizing of the low-cost sensors monitoring network.

In the future, the amount of data collected will be increased and the database could be used for other processing and purposes. The collection of traffic noise trends could be also shared and compared with data obtained in others urban areas.

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DEVELOPMENT OF OPTIMIZED ALGORITHMS FOR THE CLASSIFICATION OF NETWORKS OF ROAD STRETCHES INTO HOMOGENEOUS CLUSTERS IN URBAN AREAS

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Noise maps are considered as a powerful tool to determine the population exposure to environmental noise. A statistical approach to real-time noise mapping will be developed in DYNAMAP (Dynamic Acoustic Mapping), a co-founded project in the framework of LIFE 2013 program. The main preliminary action of the project is to define a statistically-based method to optimize the choice and the number of monitoring sites, which will provide the information to update the dynamic mapping process. In this work, preliminary results referring to a sample of roads of the city of Milan are presented. The sample database is made of 24 hour continuous acoustic monitoring of the hourly equivalent levels L_{Aeqh} in different sites, corresponding to 8 road functional classifications (from A to F and sub-classes). Once normalized, such trend profile provides a tool to group roads by their vehicular dynamics. Acoustic trend profiles will be also studied on a shorter time basis, with the aim of identifying road clusters that allow an updating of the map with an higher time frequency. Linking a non-acoustical parameter (hourly traffic flow) to the elements in each cluster represents the key-issue which allows each road segment of the urban network to be univocally assigned to the obtained clusters.

1. Introduction

Urban traffic noise has been the object of several studies aimed at investigating different aspects of its impact [1-6]. Initially, the environmental noise has been studied by using systematic sampling, that is selecting measurements points by the use of grids over a map [2]. However, this approach showed to be time and cost consuming for road administrations and local or central authorities, as well as to give more weight to noisier streets [7], thus providing biased maps. In fact, the noise on a street generally depends on its activity, the use in the urban context, width, presence of reflecting surfaces, presence of obstacles, type of paving, etc.. Acoustic simulation algorithms, implemented by software, allow to reproduce noise emission and propagation on a wide area, starting from some static information about sound sources and environment. Dynamap project has the aim to develop a dynamic approach to noise mapping, able to update environmental noise levels through a direct link with a limited number of noise monitoring terminals. Hence, the need to group road network stretches in homogeneous clusters represent a possible method to size the network of monitoring terminals. Roads sharing the same characteristics for some parameters such as vehicles' flow capacity, number of lanes, etc., are grouped together. Such parameters are usually included in the functional classification of roads and linked to the role played in the urban mobility. However, this classification generally does not reflect the actual use of roads and, therefore, the actual noise emission. For a better description of the real behavior of noise in complex scenarios such as the road network of the city of Milan, we approached the problem considering an agglomeration method based upon similarities among the 24-h continuous acoustic monitoring of the hourly equivalent L_{Aeqh} levels. Once normalized, such trend profile provides a tool to group together roads according to their vehicular dynamics, therefore allowing a more real description of such road networks.

2. Acoustic level profiles

The dataset considered in the present work refers to the city of Milan, Italy, and is made of 138 24-h continuous acoustic monitoring of the hourly equivalent levels L_{Aeqh} in 58 different sites corresponding to 8 functional road classes (from A to F and sub-groups). Sub-groups belonging to classes E and F were merged. Data were recorded on weekdays and in absence of rain as prescribed by D.M. Ambiente 16/3/1998 [8]. Because of the non-homogeneity of L_{Aeqh} level dataset, due to different monitoring conditions such as different distances from the road but also to the condition of the street itself (its geometry, the presence of reflecting surfaces and obstacles in sound propagation and types of paving), we referred each i^{th} hourly L_{Aeqhij} level of the j^{th} temporal series to the daytime reference level, L_{Aeqdj}:

$$(1)\ \delta_{ij} = L_{Aeqh_{ij}} - L_{Aeqdj}\ \text{[dB]} \qquad (i = 1\text{ h}, \ldots, 24\text{ h}; j = 1, \ldots, 58)$$

The normalization referred to the daytime L_{Aeqd} level was chosen because this descriptor is, in general, more often available than the nighttime L_{Aeqn} value. For all 58 sites, the rush-hour (time interval 7:30 a.m.-8:30 a.m.) and the night minimum (time interval 2:30 a.m.-3:30 a.m.) vehicle flow rate was available too. In 32 sites, monitoring periods extended over more days. In such cases the median of δ_{ij} hourly values was calculated. The median was chosen as this index is less influenced by the presence of outliers. Figure 1 illustrates the 24-hour mean profiles $\bar{\delta}_{im}$ (green line) and the corresponding ± the standard error of the mean for each road functional class (light green area). Due to the poor sample size (3 profiles), category A roads present higher standard error.

3. Statistical Analysis

The functional classification of roads generally does not reflect their actual use, that is the 24-h hourly L_{Aeqh} level profiles might be extremely different for roads belonging to the same category. In fact, such difference mostly depends on the activity of each road in its urban context. For this reason and as suggested in [9-10], we chose to explore our dataset by means of a cluster analysis.

For this purpose, unsupervised clustering algorithms were employed to group together level profiles found to be "close" to one another. Various algorithms (hierarchical agglomeration using Ward algorithm [11], K-means algorithm [12], Partitioning Around Medoids [13], Expectation Maximization algorithm by "mclust" module [14]) were considered, and their results compared. The number of clusters was chosen as a compromise between satisfactory discrimination and the need to limit the number of groups. The range of solutions for clustering was set from four groups (for a straightforward comparison with the number of road categories considered) to two (corresponding to the minimal discrimination). Euclidean distance was chosen as the metric of the distance among observations.

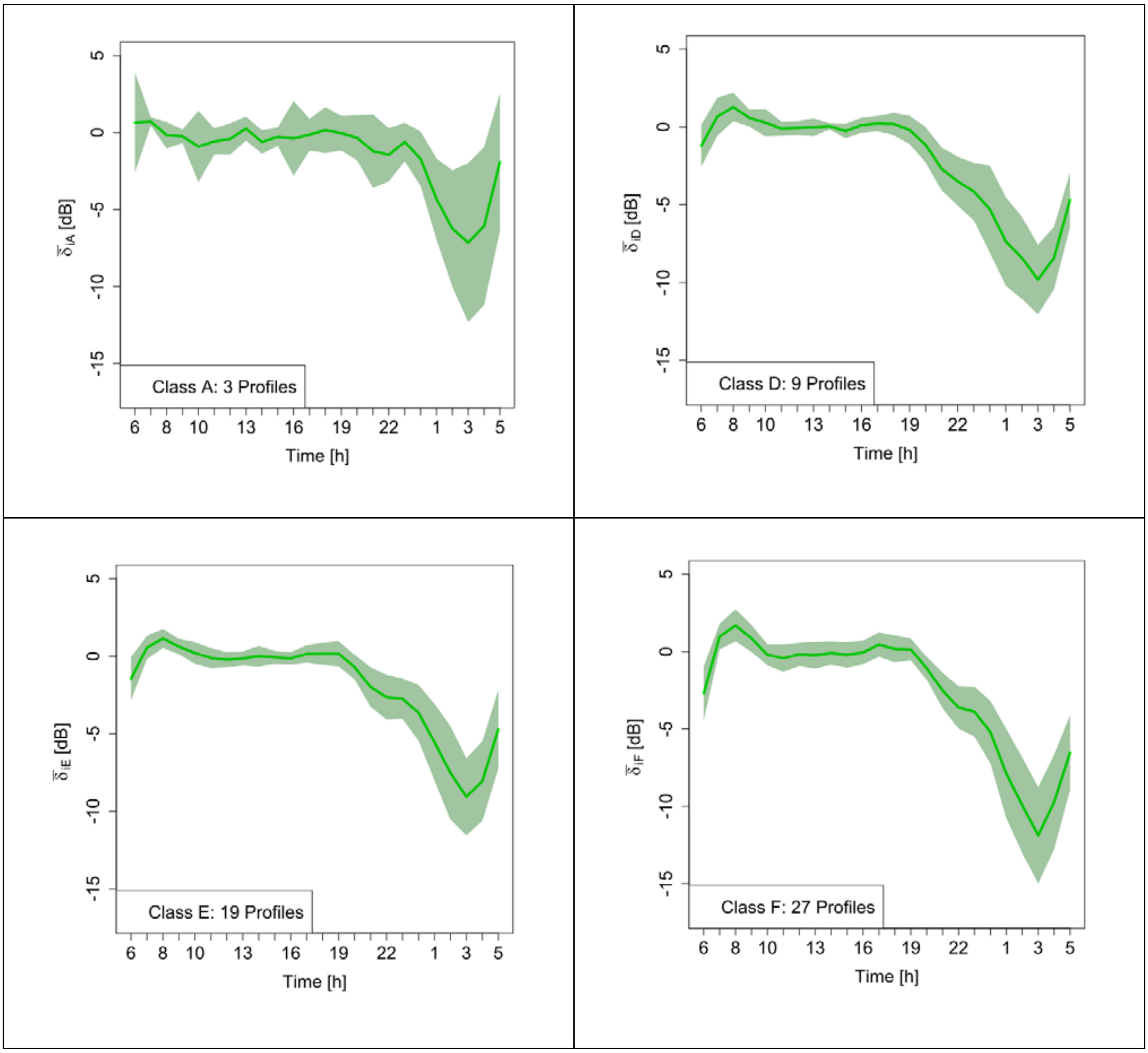

Figure 1. 24-hour mean profiles $\bar{\delta}_{im}$ (green line) and the corresponding ± standard error of the mean for each road functional class (light green area).

The statistical software R, a free software environment for statistical computing and graphics, was applied for the clustering. The package "clValid" [15-16] was used for validating the results and assess the quality of the clustering. All the clustering algorithms were ranked based on their performance as determined simultaneously by all the validation measures [17]. Thus, the optimal list, obtained through a score assigned by each validation index, gives a two-cluster K-means agglomeration at the first place followed by PAM and hierarchical methods, each one yielding also a two-cluster separation. The two-cluster groups represent a satisfying balance between an adequate differentiation among profiles and the need to get a simple practical solution. Therefore, there exists the possibility of naturally grouping the 24-h average profiles $\bar{\delta}_{ik}$ according to their shape. The obtained clusters were composed of roads belonging to different categories as reported in Tab. 1.

The two clusters appeared to be composed primarily of contributions from different temporal profiles belonging mainly to roads of category D and F for Cluster 1 (made up of 31 temporal profiles corresponding to 53.4% of total) and to roads of category A and E for Cluster 2 (made up of 27 temporal profiles corresponding to 46.6% of total).

Table 1: Composition of clusters.

Cluster	Road Category				Total
	A	D	E	F	
1	1 (33.3%)	5 (55.6 %)	6 (31.6%)	19 (70.4%)	31
2	2 (66.7%)	4 (44.4%)	13 (68.4%)	8 (29.6%)	27

This confirms that road traffic is primarily linked to the effective urban mobility use rather than its functional classification, as shown by the outcomes of previous studies [9]. Figure 2 shows the profiles of mean values $\overline{\delta}_{ik}$ and the corresponding ± the standard error of the mean for each cluster. Cluster 1 (blue line) presents two peaks: the first in the time interval 8-9 h and the second at 17 h. It fluctuates closely around the L_{Aeqd} until 19 h, afterwards it goes down in the night period till 3 h after which it starts raising again. Cluster 2 has just one lower peak at 8-9 h and higher values at nighttime. In the remaining time period, it shows a similar behavior of Cluster 1.

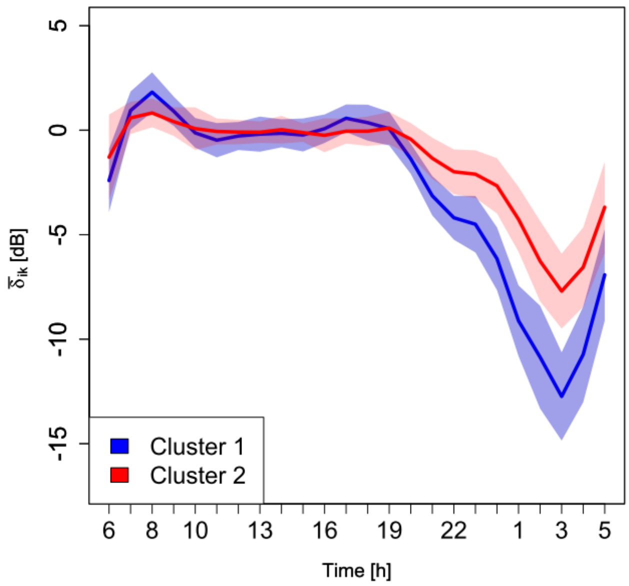

Figure 2: Mean values of $\overline{\delta}_{ik}$ and their standard error for each cluster.

Unlike the functional classification of roads, the two obtained cluster profiles cannot be applied straightforward to the whole network without any indication, which link them to a specific feature. To overcome such limitation, each mean cluster profile was associated with the corresponding traffic flow rate at rush hour (TFRH) and the night minimum vehicle flow rate (NMVF) for each of the 58 roads under consideration. Figures 3-6 show the probability density and the box plots for these parameters for the two-mean-cluster profiles. In particular, for the TFRH parameter we can observe that it presents quite separate density distributions. In addition, the interquartile range of the two clusters does not overlap. We can, therefore, consider a vehicular flow rate at rush hour of 2000 vehicles/hour as threshold between the two profiles, that is roads featuring lower values (<2000 vehicles/hour) can be associated with cluster 1 whereas higher flow rates (>2000 vehicles/hour) with cluster 2. In the case of NMVF parameter, the density distributions present different behaviors:

cluster 1 shows a sharp profile centered around zero vehicles per hour, whereas cluster 2 shows a flatter distribution though peaked at higher values. The corresponding boxplot gives distinct inter-quartile ranges for the two clusters. In this case, the threshold value between the clusters is around 40 vehicles per hour.

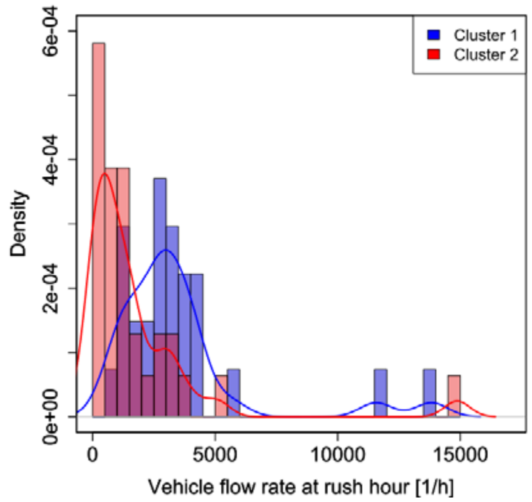

Figure 3: Histogram and probability density vs. vehicle flow rate at rush hour for the K-means two-cluster results.

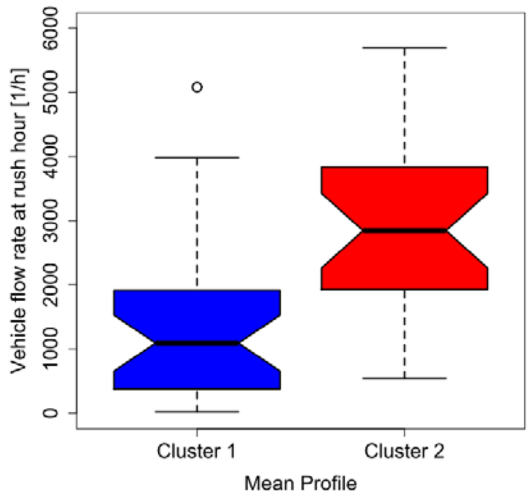

Figure 4: Box plots of the traffic flow rate at rush hour for the two mean cluster profiles.

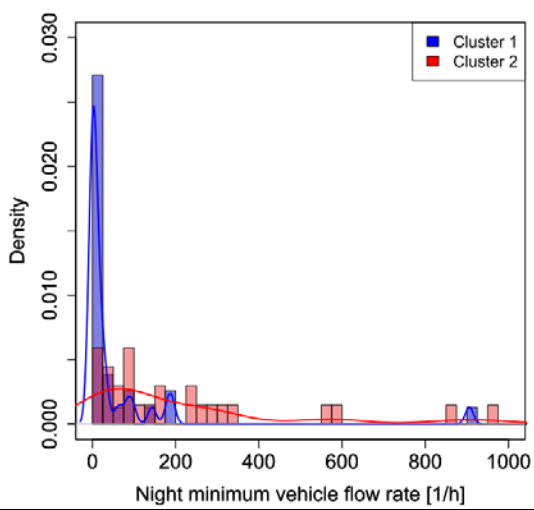

Figure 5: Histogram and probability density vs. night minimum vehicle flow rate for the K-means two-cluster results.

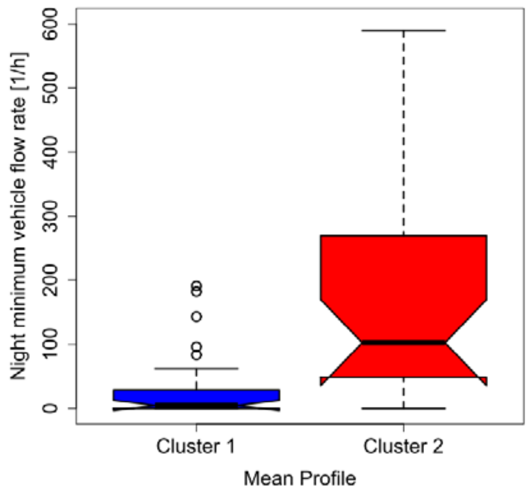

Figure 6: Box plots of the night minimum vehicle flow rate for the two mean cluster profiles.

4. Comparative analysis among profiles of different temporal discretization

Another interesting issue related to noise mapping regards the smallest time interval a noise map can be updated without losing significant information from the original data (hourly levels). To this purpose, we extracted five new level profiles with temporal resolution of 30, 20, 15, 10, 5 minutes. Unfortunately, only a sub-set of the original data was available for this operation and, therefore, each new dataset was made up of 36 sites.

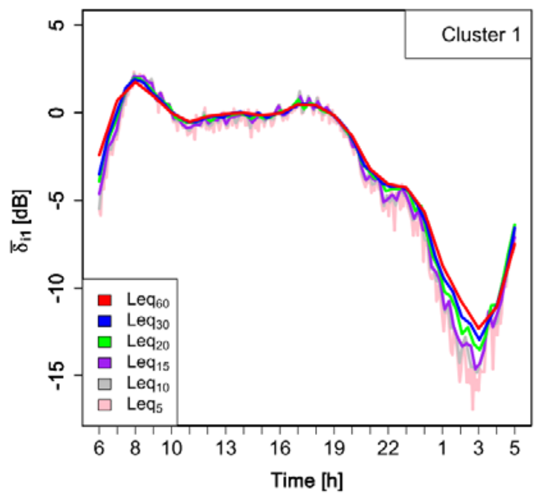

Figure 7: Comparison between the mean profiles $\overline{\delta}_{i1}$ for cluster 1 with different temporal discretization.

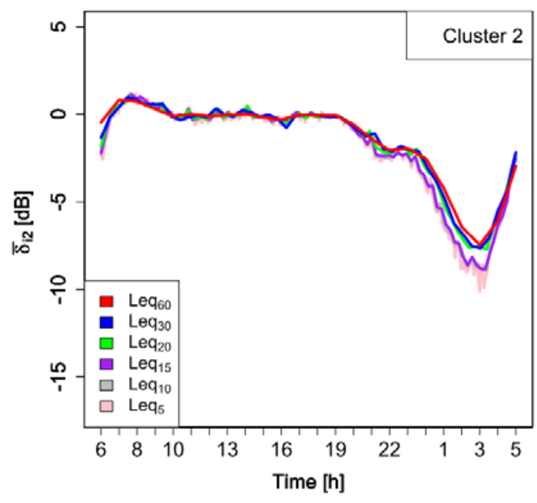

Figure 8: Comparison between the mean profiles $\overline{\delta}_{i2}$ for cluster 2 with different temporal discretization.

Table 2: Composition of clusters for different temporal discretization.

Temporal Discretization [min.]	Cluster	Road Category				Total
		A	D	E	F	
60	1	1 (33.3%)	3 (75.0%)	3 (27.3%)	12 (66.7%)	19
	2	2 (66.7%)	1 (25.0%)	8 (72.7%)	6 (33.3%)	17
30	1	1 (33.3%)	3 (75.0%)	3 (25.0%)	12 (70.6%)	19
	2	2 (66.7%)	1 (25.0%)	9 (75.0%)	5 (29.4%)	17
20	1	1 (33.3%)	3 (75.0%)	3 (25.0%)	11 (64.7%)	18
	2	2 (66.7%)	1 (25.0%)	9 (75.0%)	6 (35.3%)	18
15	1	0 (0.0%)	0 (0.0%)	3 (25.0%)	10 (64.7%)	13
	2	3 (100.0%)	4 (100.0%)	9 (75.0%)	7 (35.3%)	23
10	1	0 (0.0%)	0 (0.0%)	3 (25.00%)	10 (58.8%)	13
	2	3 (100.0%)	4 (100.0%)	9 (75.0%)	7 (41.2%)	23
5	1	0 (0.0%)	0 (0.0%)	3 (25.0%)	10 (58.8%)	13
	2	3 (100.0%)	4 (100.0%)	9 (75.0%)	7 (41.2%)	23

Each level profile with different temporal discretization was statistically analyzed and the results of the mean values, $\bar{\delta}_{ik}$, for cluster 1 and 2 are shown in figure 7 and 8. The "high resolution" temporal profiles (5, 10 and 15 min.) present quite different behavior when compared to the 60, 30 and 20 min. profiles especially in the nighttime period. This is due to the statistic process of clustering which gives different composition of the two clusters for different temporal discretization (see Tab. 2). For temporal discretization of 30 and 20 min. the composition of clusters is quite stable. In particular, cluster 1 is mainly made of roads of category belonging to classes D and F, whereas cluster 2 to classes A and E.

5. Conclusions

A completely "blind" approach has been used to analyze the 24-h continuous acoustic monitoring of the hourly equivalent levels L_{Aeqh} of different road categories aiming at searching for a better classification criterion of such profiles that reflected the actual use of roads.

The cluster analysis approach showed that the dataset of measurements can be suitably grouped into two-mean profiles to be applied to roads with vehicular flow rate less (Cluster 1) and greater (Cluster 2) than 2000 vehicles/hour at rush hour and about 40 vehicles/hour at the night minimum.

These profiles show also a different composition of the two clusters proving a loss of stability of the noise profiles for temporal resolution of 15, 10, 5 minutes.

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DYNAMAP MONITORING NETWORK HARDWARE DEVELOPMENT

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In the Dynamap project the development of a fleet of low cost sound level meters is foreseen in order to set up a wireless distributed noise monitoring system aimed at automatic updating of road noise maps. In this work, a prior art analysis on this kind of systems is presented and Dynamapp sensors technical specifications are described.

1. Introduction

The DYNAMAP project has been approved for co-financing by the European Commission through the Life+ 2013 program. DYNAMAP aims at the installation of a prototype system in the municipalities of Rome and Milan, based on pervasive low-cost hardware network for noise measurement together with some artificial intelligence algorithm to perform the automatic creation of real time noise maps. The project aims at developing a dynamic noise mapping system able to detect and represent in real time the acoustic impact due to road infrastructures. Scope of the project is the European Directive 2002/49/EC relating to the assessment and management of environmental noise (END)[1]. In particular, the project refers to the need of updating noise maps every five years, as stated in the END.

2. Projects involving distributed monitoring systems

In the last decade distributed acoustic monitoring systems started to appear, due to lowering costs of electronic components and to cheaper and smaller hardware for telecommunication. Below some projects using such technologies are listed

2.1.1 SENSEable Pisa

The SENSEable Pisa project [2], started in 2011, aims at building a network of noise sensors hosted at houses of volunteer citizens to produce in real time a detailed acoustic photograph of the territory.

2.1.2 NoiseTube

NoiseTube [3] is a research project, started in 2008 at the Sony Computer Science Lab in Paris and currently hosted by the BrusSense Team at the Vrije Universiteit Brussel, which proposes a participative approach for monitoring noise pollution by involving the general public. The NoiseTube mobile app extends the current usage of mobile phones by turning them into noise sensors enabling citizens to measure the sound exposure in their everyday environment.

2.1.3 Smart citizens

Smart Citizen [4] is a platform to generate participatory processes of people in the cities. Connecting data, people and knowledge, the objective of the platform is to serve as a node for building productive and open indicators, and distributed tools, and thereafter the collective construction of the city for its own inhabitants

2.1.4 IDEA

The IDEA project [5] focuses in particular on environmental stressors that have a very local character such as (ultra) fine particulate matter and noise. An important goal of IDEA is to develop a measurement network of less performing (and thus much cheaper) sensors that makes use of bio-inspired intelligent systems to reduce the loss of quality of global data.

2.1.5 Harmonica

The Harmonica project [6] suggests the creation of a simple, adimensional noise index, closer to the feelings of the populations than the usual averaged indicators, in a similar way to the ones used for air quality.

2.1.6 Hear-it

The EAR-IT project [7] is an EU FP7 co-funded project working over a two-years period (Oct'2012-Sep'2014) on the exiting challenges of using acoustic sensing in smart cities and smart building. With innovation and research in this area, the project experiment in the city of Santander (Spain) and for intelligent building in Geneva, applications improving security, energy saving, traffic management and more.

2.1.7 Noisemote®

Noisemote [8] is a real-time control service for environmental noise control. It has true wireless capabilities, that means no cables are really needed for powering and data transmission.

3. Categories of acoustic sensor networks

"Standard" noise monitoring system are the ones like Norsonic, Bruel&Kjaer, 01dB etc. and they are commonly used for environmental monitoring. These system are highly reliable and they are compliant with class I IEC 61672[9] or previous standards. They can work in a very wide range of environmental conditions varying from very low temperatures to highest ones and they are accurate over a wide dynamic range from 20 dB(A) to 140 dB(A). They are very expensive and not equipped for remote data transmission, so they are not well suitable for pervasive use.

In this work, sensor networks for environmental noise monitoring have been roughly distinguished in two different groups. These groups are discussed in the following sections giving some example.

3.1 Embedded pc monitoring systems

In the last decade, the exponential growth in computing technologies made possible to reduce a lot personal computer size. Actually it is possible to find small personal computer boards of sizes less than 10x10 cm at very cheap prices, equipped with high quality sound board. Such system can be equipped with gprs/3g/4g modem or Wi-Fi connection and a signal analysis software that processes incoming data from the sound board, using a cheap microphone. These kind of system present the advantage of being low cost and they can be remotely fully updated and reprogrammed. Moreover they can be coded with specific algorithm executing particular complex tasks as noise recognition, source position tracking etc. The disadvantage of those systems is the power consumption, that is actually at least 2-3W, so there is the need of power supply or big solar panel making difficult the application for pervasive monitoring.

3.2 Units with microcontroller and digital signal processor

The main advantage of this kind of system is the possibility to implement low power applications (200 mW mean equivalent consumption or less) that permit to power these devices with solar panels or with other energy harvesting systems. The disadvantage of those systems is the limited possibility to modify and remotely control the device in order to implement complex tasks. “Standard” noise monitoring systems can be included in this group.

4. Dynamap sensor specifications

The Dynamap objective is to render noise maps will faithfully represent the noise levels caused by road infrastructures solely, so anomalous events need to be eliminated. It will be used a supervised learning technique consisting of two main processes: i) signal feature extraction, and ii) noise event recognition. On one hand, the signal feature extraction process aims at obtaining a set of numeric coefficients (or features) representing the acoustic characteristics of the noise signal. On the other hand, the noise event recognition process should automatically decide whether the noise signal corresponds to road traffic noise or not.

Due to prototypal nature of the sensors network to be installed, it is advisable to use a flexible system, precisely like embedded computers, that can be remotely accessed and programmed in order to run specific audio processing scripts. Another opportunity given by this choice is to preprocess data onboard, reducing the size of data streaming to the central server that will make the final task of recognizing the acoustic events. This will also guarantee better scalability of the system, reducing the computational load on the central server when the number of sensing units is increased.

A first set of basic specifications has been defined for each monitoring station and it is listed below:

- 40-100 dB(A) broadband linearity range
- 35-115 dB working range whit acceptable THD and narrowband floor noise level
- 1 second time base 1/3 octave spectrum
- Possibility of audio recording
- VPN connection
- GPRS/3G/WiFi connection

5. Conclusion

In this paper some basic technical specifications of acoustic sensors to be used in the Dynamapp project have been listed. Due to the prototypal nature of the whole system, the use of embedded computers seems to be the simplest way to perform all the task required and to permit a direct remote control on each monitoring node.

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DEVELOPMENT OF AN ANOMALOUS NOISE EVENT DETECTION ALGORITHM FOR DYNAMIC ROAD TRAFFIC NOISE MAPPING

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Dynamic road traffic noise maps should display, in real time, the noise levels generated by road infrastructures measured by the sensors located on the road. For this reason, any acoustic event produced by another source that could alter the measured noise levels (e.g. an aircraft flying over, nearby railways, church bells, crickets, etc.) should be detected and eliminated from the map computation to provide a reliable picture of the actual road noise impact. To that end, it becomes necessary to devise strategies to automatically identify anomalous noise events captured by the network of sensors. This work describes a first version of the anomalous noise event detection algorithm designed in the LIFE DYNAMAP project. The proposed algorithm follows a "detection-by-classification" approach based on a semi-supervised two-class classifier that does not require training with on-site collected "anomalous noise events" samples, thus being location-independent. Instead, it optimizes a decision threshold based on distance distributions with respect to the predominant "road traffic noise" class to maximize detection accuracy. The experimental results reveal that our proposal outperforms the baseline two-class supervised detector especially in scenarios in which anomalous events show higher noise levels and, thus, are more likely to alter the levels represented in dynamic road traffic noise maps.

1. Introduction

Traffic noise is one of the multiple sound sources that, especially in urban environments, cause a negative impact on the quality of life of the population [1]. In fact, environmental noise has been found to cause harmful health effects, for instance, being highly correlated with cardiovascular diseases such as myocardial infarction and hypertension [2]. In order to face this situation, the European Commission promoted the Environmental Noise Directive 2002/49/EC (END) with the aim of informing citizens about their exposure to noise and drawing up appropriate action plans to prevent the harmful effects derived from noise exposure [3]. The reporting of acoustic levels caused by different sources (among which traffic noise is a relevant one) by means of noise maps is one strategic action plan to promote policies based on END. These noise maps usually have been implemented by computing the averaged noise levels during one year and being reviewed (and revised, if needed) once every five years [3]. However, the implementation of dynamic noise maps that reflect more precise data about harmful sound sources in real time not only allows more detailed assessments, but also checking the effectiveness of the conducted noise actions plans in short term, among other advantages. Following this goal, acoustic sensor networks that monitor the noise levels in urban areas have been recently proposed (e.g. see [4,5]).

The system proposed in this work locates within the European LIFE DYNAMAP project (Dynamic Acoustic Mapping - Development of low cost sensors networks for real time noise mapping). This project aims at easing the update of noise maps and at reducing their economic impact through the development of an automatic and integrated system for data acquisition and processing capable of detecting and representing, in real time, the acoustic impact due to road infrastructures by means of dynamic noise maps. The DYNAMAP system is composed of networks of low cost sensors measuring the sound pressure levels emitted by the traffic noise sources and of a software tool based on a geographic information system (GIS) platform performing real time noise maps updating. To increase its robustness, the DYNAMAP system will include an anomalous noise event detection (ANED) algorithm to avoid that non-traffic acoustic events alter the noise maps scaling.

The key contribution of this paper is a location-independent ANED algorithm based on a two-class ("road traffic noise", or RTN, vs. "anomalous noise event", or ANE) "detection-by-classification" approach. In a road traffic noise monitoring context like the DYNAMAP project, the presence of anomalous noise events can be *i)* highly local (e.g. sensors located in roads near airports will often capture aircraft noise while others will rarely be affected by this type of noise), *ii)* unpredictable and highly diverse (e.g. ambulance sirens or thundering), and *iii)* little likely to occur (e.g. a bird or a cricket that approaches the sensor). For these reasons, collecting a sufficient number of anomalous noise events samples that represent this high diversity of possible noise sources to accurately train the classifier would require a great effort. To circumvent this inconvenience, we propose a location-independent ANED algorithm based on a semi-supervised approach that avoids creating acoustic models for the minority ANE class. Instead, we employ distance-based classifiers and optimize a decision threshold based on distance distributions with respect to the predominant RTN class. In our experiments, we compare this approach to a classic two-class supervised classifier (used as a baseline) that creates acoustic models for both classes.

The algorithm has been evaluated on a dataset of synthetic mixtures of anomalous events and road traffic noise. The experimental results show that the proposed scheme outperforms the baseline detector in terms of recognition and detection rates especially in those scenarios in which ANE have higher pressure levels.

The paper is organized as follows. Section 2 describes several state-of-the-art approaches to noise event detection and recognition. Section 3 presents a description of the proposed system, and also its main implementation details: features, machine learning algorithms, and threshold decision optimization criteria. In Section 4, the conducted experiments and the obtained results are described and discussed. And finally, the Section 5 draws up the conclusions and future work.

2. Related work

Audio event detection is the task of finding the start and end points of a noise event of interest within a continuous audio stream. Focusing on the detection of environmental sound events, it is important to highlight that they are usually disconnected from one another (in contrast to what happens in speech or music, which present a strongly interconnected temporal "structure" composed of phonemes or notes, respectively [6]). For this reason, the detection of environmental sound events in a continuous audio stream is typically tackled by one of the two following approaches.

The first approach is based on using a novelty-detection system that considers any rapid change against the long-term background noise to be a sound event. This type of approach is usually referred to in the literature as "detection-and-classification". The second alternative consists in using a sliding window detector that performs classification on each fixed-length segment in turn. This approach is commonly referred to as “detection-by-classification” [7].

The former type of approaches to audio event detection (i.e. “detection-and-classification”) do not require being trained on labeled data, which makes them very adaptable to new auditory environments. One the first relevant examples of this type of audio event detection systems was presented in [8], based on the idea that abrupt changes in sound usually indicate a new event has occurred. To detect such abrupt changes, the authors computed a time series of temporal and frequency feature vectors over the audio stream, using the Mahalanobis distance to compare successive frames.

To compare adjacent frames in a more robust fashion, other metrics such as cross-correlation and energy spline interpolation were introduced [9]. Later, the same authors proposed the use of transient models based on dyadic trees of wavelet coefficients to clearly detect impulse noise events [10].

Lately, “detection-and-classification” approaches have shifted towards the use of sequential hypothesis testing [11]. For instance, Dessein and Colt [12] applied these techniques to real-time audio segmentation using the information geometry of exponential families. In [13], the authors showed how segmentations and similarities between neighboring frames can be computed in an information-geometric context by finding the centroids for each audio segment.

A very recent approach to audio event detection is based on the application of unsupervised learning techniques, such as clustering [14]. In this approach, the expressiveness of the model is exploited to discover the correct segmentation. To that end, several online learning algorithms are developed to apply Hidden Markov or semi-Markov Models based on incremental optimization schemes to the audio segmentation task.

On the other hand, the “detection-by-classification” approach performs classification of sequential audio segments, where the detection window shifts forwards over time. The output at each step is then a decision between noise and one of the trained sound events. Thus, here we need a classifier trained to detect the noise events of interest. According to [6], the advantage of this approach is that only one set of features needs to be extracted from the audio as the detection and classification modules are combined. The main disadvantage lies in choosing an appropriate window size and classification method capable of working well across a range of experimental conditions.

A relevant work in this type of detectors is the two-stage audio event detection system based on Support Vector Machine (SVM) classifiers described in [7]. In the first stage, silence/non-silence segmentation is performed. In the second stage, the sound occurring in the non-silence segments are classified into a series of predefined classes by means of SVM classifiers. The use of Hidden Markov Models (HMM) applied to audio event detection was the focus of [15]. In that work, the authors use the Kullback-Leibler distance to quantify the discriminant capability of speech feature components in acoustic event detection. Based on these distances, they use AdaBoost to select a discriminant feature set. More recently, Zhuang et al. proposed extracting discriminative features for audio event detection using a boosting approach [16], leveraging statistical models (a tandem connectionist-HMM plus an SVM–GMM-supervector approach) that better fit the audio event detection task. The use of part-based decompositions of the incoming audio stream is another recent approach to audio event detection. In [17], the authors proposed an approach to detect and model acoustic events that directly describes temporal context, using convolutive non-negative matrix factorization (NMF). The recent work by Schroder et al. on audio event detection has covered several alternatives of the “detection-by-classification” approach to tackle this task. For instance, the authors proposed in [18] an acoustic event detection system consisting of a noise reduction signal enhancement step, a Gabor filterbank feature extraction stage and a two layer HMM as back-end classifier.

The anomalous noise event detection presented in this work belongs to the latter type of detectors, i.e. “detection-by-classification”. The next section presents a detailed description of its rationale and components.

3. System description

The ANED algorithm designed to automatically detect anomalous noise events follows a pattern recognition approach divided into two main steps: signal feature extraction and recognition. The recognition stage is tackled by supervised machine learning techniques. This requires training the system with noise samples with their corresponding labels in order to build acoustic models that allow recognizing different noise classes.

In the context of our problem, it would be sufficient to train the classifier with N=2 noise categories, as our goal is to detect the presence of noise events other than road traffic noise. Figure 1 depicts the block diagram of a generic 2-way "detection-by-classification" system, referred to as the *baseline* detector hereafter. Notice that two phases are envisaged: *i)* a *training+validation* phase, in which, firstly, one acoustic model per class is built after the parameterization of labelled *training* data (through windowing and feature extraction); and secondly, internal parameters of the classifier are tuned using labelled *validation* data of both classes; *ii)* an *operation* phase, in which the classifier assigns one of the two possible noise class labels to each frame of an unknown noise signal.

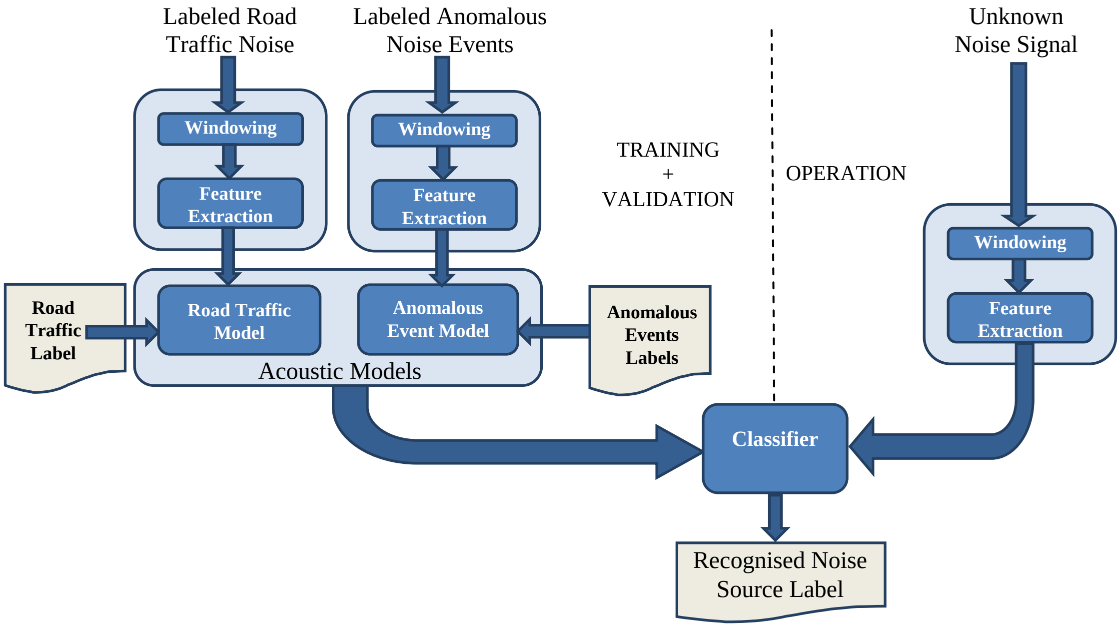

Figure 1. Block diagram of a baseline 2-way "detection-by-classification" system based on supervised learning.

Since DYNAMAP acoustic monitoring stations will be placed in a fixed location, it would be possible to train the ANED algorithm accurately by collecting a sufficient number of samples of both noise classes at each sensor's location. However, the highly local, occasional, diverse and unpredictable nature of most types of anomalous noise events makes sample collection a repetitive, difficult and burdensome task. For this reason, in this work we propose a location-independent semi-supervised 2-way "detection-by-classification" ANED system that minimizes the need for anomalous noise events samples collection, avoiding training with on-site collected noise samples.

3.1 Proposed ANED algorithm

Figure 2 shows the block diagram of the proposed anomalous noise event detection system. One of the main differences with regard to the baseline system depicted in Figure 1 is that anomalous events are now used only for adjusting a decision threshold, and no acoustic model is built for this class.

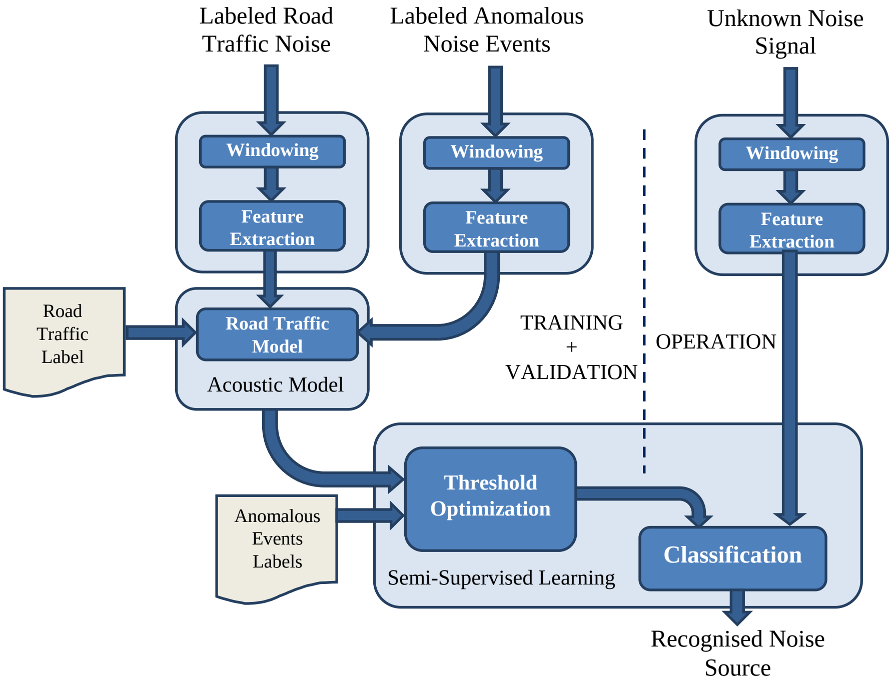

Figure 2. Block diagram of the proposed anomalous noise event detection system.

From an operational perspective, the proposed system uses *training* data corresponding to road traffic noise during the training phase to build the acoustic model of the RTN class. Next, a *validation* data set containing samples of both the RTN and ANE classes is employed to adjust the threshold that allows measuring the proximity of the signals of both classes to the learned RTN acoustic model. Although this decision threshold could be fixed heuristically, a more precise value can be obtained by a simple analysis of the two-class (RTN and ANE) distances distributions, obtained from the classifiers responsible for the detection. Finally, the system enters the *operation* mode, in which unseen noise samples are classified either as RTN or ANE.

The following paragraphs describe the constituting modules and implementation details of the proposed ANED system, namely: signal parameterization, classification algorithm and decision threshold optimization.

3.2 Signal parameterization

The signal feature extraction block of the ANED algorithm parameterises the noise signal by means of a fixed-size set of coefficients that model the spectro-temporal characteristics of the noise signals. To this end, first the input signal is segmented into 30 ms frames using a Hanning window. Subsequently, a feature set is extracted from each signal frame. In this work, we have selected the biologically-inspired Gammatone Cesptral Coefficients (GTCC), which have recently shown an improved performance in environmental sound recognition tasks [19]. Also, Mel-Frequency Cepstral Coefficients (MFCC) are compared to GTCC in the experiments for being a classic baseline benchmark. The number of computed coefficients is 13 for both GTCC and MFCC.

3.3 Supervised classification

In this work we consider two simple but effective classification techniques: K-Nearest Neighbour (KNN) and Fisher's Linear Discriminant (FLD). The choice of these two classification techniques is motivated by the fact that they both provide a certain distance measure that can be interpreted as a measure of similarity between the dominant class (i.e. RTN) and the input noise frame, which will be the base for adjusting the detection decision threshold. For KNN, this is the distance between the input noise frame and the K closest training examples. In case of FLD, this measure corresponds to an estimation of the log probability that road traffic noise is the source of the input frame (thus, a value close to 0 shows high similarity to this class while high negative values show that the input could be an anomalous event).

As for the internal configuration of the KNN classifier, the validation set allowed deciding that the KNN would employ the Euclidean distance metric and consider the K=3 nearest neighbours.

3.4 Decision threshold optimization

The proposed technique for setting the decision threshold is based on obtaining an equally minimum value of both type I and type II errors (false positives and false negatives), as in [20], where the same criteria was adopted with the aim of obtaining an optimal speaker verification system. This threshold adjustment is performed by using samples from the validation dataset (see Section 4.1).

4. Experiments

4.1 Audio database

The audio database used for the experiments consists of real road traffic noise (RTN) recordings of the ring road surrounding the city of Barcelona, synthetically mixed with anomalous noise events (ANE) samples (containing up to 15 noise types, like horns, ambulance sirens, car collisions, church bells, birds, crickets, rain, thunders, etc.) gathered from free online repositories. Road traffic noise free field recordings were obtained using the Brüel & Kjaer 2250 sonometer, with 48 KHz sampling rate, 4.2 Hz - 22.4 kHz broadband linear frequency range and its own microphone (Type 4189). The total length of sound samples used for training is 250 seconds of RTN and 300 seconds of ANE. Finally, to test the system in scenarios in which ANE had different degrees of relevance, the level of each type of noise in the mixtures was adjusted to obtain RTN-to-ANE ratios of -6 and -12 dB.

4.2 Baseline techniques and experimental setup

The evaluation process is performed following a 4-fold cross validation scheme. In each repetition, *training + validation* and *test* subsets are changed so as to obtain statistically reliable results. As regards the baseline detector, *training*+*validation* data (75% of the total available data) contains both classes (RTN and ANE). In contrast, in the proposed ANED algorithm, *training* data (12.5% of the total available data) contains only RTN class, while the *validation* set (12.5% of the data) contains RTN and ANE samples.

4.3 Results

Table 1 presents the results of the conducted experiments in terms of two evaluation metrics: *i)* the F1 measure of the ANE class ($F1_{ANE}$), computed as the harmonic mean between *precision* (ratio between the true positives and the total amount of frames classified as ANE) and *recall* (ratio between the true positives and the total amount of true ANE frames); *ii)* the total classification rate R in % (averaged percentage of the testing samples correctly classified).

The performance of the proposed ANED algorithm is compared to that of the baseline detector for RTN-to-ANE ratios of -6 and -12 dB, using the FLD and KNN classifiers, as well as GTCC and MFCC features.

4.4 Discussion

It can be observed from Table 1 that the proposed ANED algorithm outperforms the baseline detector in terms of both evaluation metrics in most cases. Specifically, the proposed method attains better results in five of the eight experimental scenarios. In particular, the best recognition accuracy

Table 1. Results of the conducted experiments. The best results for each combination of RTN-to-ANE vs. Classifier vs. Features are highlighted in boldface.

		RTN-to-ANE = -12 dB				RTN-to-ANE = -6 dB			
		FLD		KNN		FLD		KNN	
		GTCC	MFCC	GTCC	MFCC	GTCC	MFCC	GTCC	MFCC
Baseline	$F1_{ANE}$	0,7877	0,7990	0,8305	**0,8266**	0.6983	**0.8233**	0.7738	**0.8478**
	R (%)	85.25	85.62	87.26	**86.42**	77.43	84.58	**83.77**	**87.12**
ANED	$F1_{ANE}$	**0,8976**	**0,8397**	**0,8440**	0,7710	**0.8252**	0.7906	**0.7810**	0.6718
	R (%)	**91.46**	**87.22**	**87.70**	83.35	**84.56**	**84.79**	79.97	76.82

and $F1_{ANE}$ are obtained for the configuration that considers using the proposed ANED scheme, FLD classifier, GTCC features and RTN-to-ANE = -12 dB (91.46% of recognition rate and 0.8976 value of $F1_{ANE}$).

It is important to note that the ANED performs better than the baseline detector especially in the most adverse scenario as regards the presence of anomalous noise events (RTN-to-ANE = -12 dB), which is particularly important in the context of the DYNAMAP system.

5. Conclusions

In this paper, a new strategy for conducting anomalous noise event detection in road traffic noise monitoring systems has been proposed. The technique is based on a distance-based classifier trained with RTN samples, and a subsequent decision stage in which a threshold is optimized by using both RTN and ANE samples. Preliminary experiments have been conducted using synthetic mixtures of RTN recordings and ANE samples obtained from the Internet, with the aim of validating the viability of the proposed approach. It is worth mentioning that the ANE dataset used for training and validation is small, especially considering the high diversity of possible non-traffic noise sources. The obtained results confirm that the proposed ANED method can outperform the baseline "detection-by-classification" algorithm in most of the simulated scenarios, especially in those with lower RTN-to-ANE ratio (i.e. those situations in which anomalous noise events are more likely to distort the pressure levels represented in the dynamic traffic noise maps, which is the case we need to address more specifically).

Further research will be oriented towards several directions, such as the exploitation of the temporal dynamics of the detection to increase its robustness, the evaluation of different system setups (e.g. different features sets and classifiers), the exploration of early and late fusion schemes, and the investigation of how the proposed location-independent approach can be adapted and optimized to perform in specific acoustic environments.

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BASIC SECONDARY ASPECTS OF THE LIFE DYNAMAP PROJECT

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In this work some basic secondary aspects of the DYNAMAP project, a LIFE+ project on dynamic noise mapping co-financed in the framework of the LIFE 2013 program, will be described and discussed. Such basic secondary aspects include relevant issues that could strongly influence the success of the project, namely benefits and costs of the proposed solution, public response and user ability in consulting and managing the system (in compliance with the Environmental Noise Directive 2002/49/EC), future development of the system applications. As for the first aspect, an in depth cost-benefit analysis is foreseen in the project in order to demonstrate the possibility of reducing the resources needed to update noise maps (time, costs and dedicated personnel) through the noise mapping process automation. With regard to information and communication to the public, the DYNAMAP system will deliver a tool where simplified and easy-to-read noise maps will be made available to inform the public about noise levels and actions to be undertaken by local and central authorities to reduce the noise impact on the environment. The tool will be structured with different access levels to the system data base and tested to check public response and user ability in consulting and managing the system. Finally, the DYNAMAP project will investigate the possibility of strengthening the system with applications for dynamic reporting of integrated environmental impacts (noise, air quality, meteorological conditions, etc.), so as to provide a more comprehensive and complete overview of the environmental impact of road infrastructures present in the monitored areas.

1. Introduction

The main aim and outcome of the Dynamap project is the provision of dynamic noise maps able to detect and represent in real time the acoustic climate of road infrastructures. The success of the project, could be, however, strongly influenced by the fulfilment of some secondary objectives, such as the reduction of costs, the public response and user ability in consulting and managing the system, as well as the future development of the system applications.

Indeed dynamic noise maps, although very appealing, could be inapplicable if their cost were judged unsustainable. Likewise, their added value would be negligible if the possibility of collating many data in real time couldn't be exploited to provide useful applications, such as the control and management of traffic to reduce noise emissions, the upgrade of the system towards smart integrated environmental maps (including air pollutions indicators, traffic flow information and meteorological conditions), user-friendly tools to inform and communicate to the public.

In the following paragraphs the issues of costs and benefits, public information and communications and the future upgrade of the Dynamap system will be discussed in details so as to provide a comprehensive overview of its wider benefits and potential exploitation.

2. Expected cost and benefits of the Dynamap System

The project includes a comprehensive costs and benefits analysis in order to assess the feasibility and economic sustainability of the Dynamap system on a large scale. Aim of this study is to demonstrate that noise mapping costs can be reduced and that benefits can be improved by providing updated real time information on the acoustic climate of road infrastructures at any place and time. As a matter of fact, the success of the project mostly depends on the economic burden required to local and central authorities for implementing the system compared to costs and benefits associated to traditional noise mapping procedures. Therefore, costs and benefits can't be considered secondary aspects for the success of the project, but basic specifications to be fulfilled to reach the final goal.

The cost-benefits analysis will be at first carried out locally in the two pilot areas foreseen in the project (i.e. the A90 motorway surrounding the city of Rome and Milan district n° 9), and then extended to the whole ANAS network and the agglomeration of Milan, to demonstrate the feasibility and economic sustainability of the system. The study includes the development of a standardized method for assessing costs and benefits based on the most recent results available in literature. The analysis will be referred to a static scenario prepared following the traditional noise mapping procedures and will be accomplished in three steps.

In the first step costs related to the implementation of traditional and dynamic noise maps will be collated and costs estimates on a large scale will be accomplished. Costs will be extended and updated taking into account a time horizon of 20 years (4 END cycles). A standard method for costs evaluation will be provided and a simple tool running on a general purpose platform (i.e. Excel) will be developed to help local authorities and transport administrations proceeding with a detailed costs analysis.

In the second step, benefits will be identified and quantified taking into account the effects associated to the efficiency of the two options in terms of rapidity of response, evaluation accuracy and impact on the population. Further aspects linked to socio-economic effects will be also included to determine the benefits resulting from changes on social costs due to the implementation of the system. To monetize those costs coefficients available in literature, opportunely adapted, will be used.

In the third step, a cost-benefit analysis of the Dynamap system will be accomplished to assess the feasibility and economic sustainability of the Dynamap system on a large scale. Costs and benefits resulting from previous steps will be used to determine the economic impact of the Dynamap system. Next, the Net Present Value (NPV) will be calculated to assess the feasibility of the Dynamap system on a large scale and the Benefits/Costs Ratio (BCR) will be determined to evaluate its efficiency.

Finally, the system recovery time and non-monetized components (risks and political consequences) will be assessed to complete the impact analysis of the proposed solution.

As a starting point, a first rough estimate of the expected costs of the system will be given and compared to costs related to traditional noise mapping methods. Then, during the life of the project, costs will be constantly monitored and updated in order to provide a final reliable assessment of the Dynamap System economic impact as a whole.

2.1 The Costs of traditional noise mapping activities

The cost of noise mapping activities has been investigated and reported by the CEDR (the Conference of European Directors of Roads) Working Group Road Noise in 2013. Costs were collected through a questionnaire referred to the first cycle of strategic noise mapping (END) sent to all CEDR Member States. Results from the questionnaire show that costs depend substantially on the possibility of outsourcing or arranging in house activities. In particular, six out of seventeen respondents reported in house noise mapping activities with an average cost of €160. Outsourced costs, instead, ranged from € 6.500 for mapping 11 km to € 8.000.000 for mapping 17.000 km with an average value of 604 € per kilometer with peaks higher than 1.500 €. In Fig. 1 the results of the survey are shown 1.

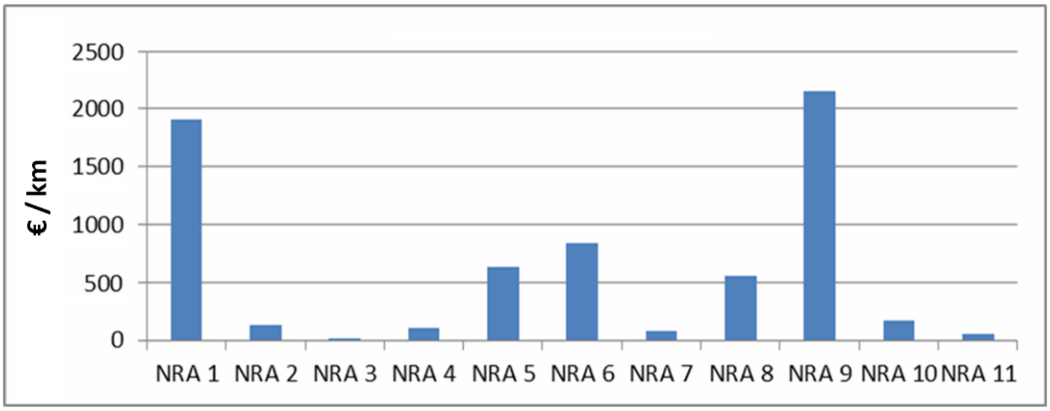

Figure 1. Noise mapping costs provided by eleven National Roads Administrations (NRA) for the first cycle of strategic noise mapping (END)[1].

Costs differences can be attributed to many factors, such as the availability of basic information to noise map the road network (traffic flow, cartography, meteorological data, number of inhabitants, etc.). Therefore, when basic information was not available, expensive measurement campaigns were necessary to collect data and estimate noise levels.

2.2 Expected costs of the Dynamap system

A first rough estimate of dynamic noise mapping costs has been accomplished with a simple calculation referred to the expense that should be paid in the Dynamap project to prepare the pilot area located along the A90 motorway that surrounds the city of Rome, where a minimum number of 25 monitoring stations will be installed (1 device every 2 km). The calculation includes the cost of the monitoring stations, their installation and maintenance for twenty years, the cost related to the preparation of the basic noise maps. A cost of 545 €/km has been estimated using customized low-cost devices. However, it should be noted that the latter refers to prototype and that a cost reduction of 70% is expected when the devices will be fully developed and made available as standard items. Likewise, costs for installation and maintenance can also be decreased to 20% if planned together with other ordinary maintenance activities (i.e. road lighting maintenance, road panels maintenance, etc.). In the end, a value of 125 €/km can be achieved for hardware and software provision, installation and maintenance. This cost doesn't include the preparation of the first set of basic noise maps (150 €/km), that should be added to the latter figure to obtain the final cost of 275 €/km, whose value is less than a half of the average cost reported by CEDR2.

3. Public response and users ability in consulting and managing the system

Another aspect that could influence the success of the project relies on public response and users ability in consulting and managing the system. The project will have a greater chance of attracting the public interest if user friendly interfaces and tools will be developed, so as to make the information gathered by the system usable on a large scale through easy to access applications, in accordance to European directives communication rules. In the following paragraphs, a detailed description of the project's contribution to meet such requirements is reported.

3.1 Public information and communication requirements from END

Public information and communication rules and obligations are based on the Directive 90/313/EEC3, that enforces public authorities to give free access to environmental information, setting out the basic terms and conditions on which such information should be made available. According to this directive, Member States shall ensure that public authorities make environmental information available to any natural or legal person at his request and without his having to prove an interest. They shall also define the practical arrangements under which such information is effectively made available and shall take the necessary steps to provide general information to the public on the state of environment by such means as the periodic publication of descriptive reports.

In 2002 the obligation of providing environmental information and communication to the public was introduced in the Directive 2002/49/EC on environmental noise (END). According to ENDMember States shall ensure that strategic noise maps and action plans are made available and disseminated to the public in compliance with National and European standards. This information shall be clear, comprehensible and accessible. Furthermore, Member States shall ensure also that the public is consulted about proposals for action plans, given early and effective opportunities to participate in the preparation and review of the action plans, that the results of that participation are taken into account and that the public is informed on the decisions taken. As a matter of fact, involving the public in the preparation of noise action plans is one of the fundamental requirements of the END. According to the END, the most appropriate information channels should be properly selected in order to have a wide spread of information to the public 4.

3.2 State of the art on public information and communication

In 2013 the CEDR Project Group Road Noise published a report on action plans, where the issue of informing and communicating to the public was analysed to evaluate the effectiveness of the strategies used to boost the participation of the public in preparing and selecting the most appropriate mitigation measures. The survey involved seventeen National Roads Administrations (NRA) of many Member States.

In all Member States, public consultations were conducted after the release of the draft action plan. Information and consultations were solicited through advertisements in newspapers (80%), NRAs websites (100%) and public hearing meetings (30%). A consultation period of at least 8 weeks was provided to ensure a reasonable time-frame to prepare appropriate proposals. Public participation in consultation activities ranged from 0 to 154 and varied from Member State to Member State.

Despite the common agreement on the importance of consulting the public about Noise Action Plans, the survey also highlighted that get the public involved in the hearing process is not an easy task and that consultation activities gave no useful feedback 5.

Another interesting experience on public information was carried out within the Life project Harmonica, where innovative tools were developed to better inform the public about environmental noise and to help local authorities in the decision making process. To improve public comprehension on noise issues and impacts, the Harmonica project suggested the creation of a simple, dimensionless noise index, closer to the feelings of the populations than the usual averaged indicators, in a similar way to the ones used for air quality. Besides, a database on noise abatement actions was created and published on an interactive platform to share useful information and experiences. Thanks to this innovative tool, all relevant information was made available in an easy-to-understand way, facilitating the assessment of the impact of noise abatement actions. This collaborative platform 6, open to all stakeholders involved in fighting noise nuisances, was intended to ease the work of decision-makers by bringing together experiences, innovations, and action plans.

3.3 The communication approach foreseen in the DYNAMAP project

The core idea of the Dynamap project is based on the possibility of implementing a software able to dynamically update noise maps in real time. The software output, as a GIS file, will feed another software application for real-time web presentation of the results to the public.

The latter will be able to read data coming from the system, and depict noise values as colored geo-referred noise maps to be published on the system's web site in a user-friendly format.

Access to data will be granted according to the privilege assigned to different users categories. Two main types of privilege will be defined: low and high. The first category includes the general public, while the second one comprises authorized stakeholders. Users with low privilege will be able to plot only noise maps, while users with high privilege will be able to see the time history of noise levels, some statistics and additional parameters linked to the sensors installed in each monitoring station. This software application will be also designed to plot other environmental data, in addition to noise maps, such as air quality, weather and traffic conditions, when available.

To optimize the software application communication skills, the project foresees an iterative process where users ability in accessing information and managing the system will be checked through a series of tests.

Two test steps are foreseen. The first step includes two sessions, with a time gap of one month, to check users ability in learning and managing the Dynamap tools. If necessary, some corrective actions will be undertaken to meet users requirements and a last test will be accomplished to provide a final assessment of the Dynamap system interface.

For each session, two kind of tests will be prepared. The first test type will be addressed to system's operators and aims at assessing users ability in managing the system. The test will include direct observation of system managing skills and the compilation of a technical evaluation form.

The second test type will be addressed to stakeholders and the general public. In this case, the test will require a remote access to the system through the project website and the compilation of a short questionnaire to collate information about users reactions. The questionnaire will include questions on project tools capability of raising people awareness on noise through freely accessible information and communication from the website, such as educational applications to explain citizens roles as subjects exposed to noise, but also as generators of noise, information on noise effects on health, environmental laws, the influence of driving habits on noise levels, the exposure to noise and the solutions that could be applied to abate noise (comparison between different scenarios).

Finally, the project includes the monitoring of action plans preparation for the agglomerations of Milan and Rome, to check the effectiveness of the information delivered to the public and verify their actual participation in selecting and adopting proper noise mitigation measures. As consequence of the results achieved, corrective actions will be taken to meet users requirements and improve the accessibility of the software interface.

4. Future vision on system applications

A very relevant aspect as regards the deployment of the DYNAMAP system on a large scale is related to its evolution from its original conception towards a more complete, multimodal and informative tool. Indeed, endowing the DYNAMAP system with capabilities beyond the real time mapping of road noise traffic can be a distinctive factor that increases its acceptance and attractiveness.

For this reason, the development of the DYNAMAP project foresees two actions addressing how to upgrade the system by adding environmental sensors to the DYNAMAP monitoring stations and how to obtain information for traffic management and control from the sensors.

The following sections describe the rationale, main goals and activities undertaken in those two actions of the project.

4.1 System upgrade with added environmental sensors

One of the main features of the DYNAMAP system resides in its capacity of implementing a dynamic graphical representation of road traffic noise. Despite the importance of such maps as a tool for updating noise maps as required by the European Directive 2002/49/EC relating to the assessment and management of environmental noise (END), the interest of authorities and the general public in the DYNAMAP system could be limited due to the restricted scope of the mapped data. However, it is not difficult to conceive that such real time maps could be extended and adapted to display dynamic information about other environmental parameters. This extension of the DYNAMAP system is envisaged as a means for increasing its attractiveness and interest.

For instance, DYNAMAP maps could be extended to inform about the volumetric concentration of pollutant agents in the atmosphere, thus providing a visual and constantly updated map of air quality. Another example could be the creation of maps displaying the value and evolution of meteorological parameters, such as air humidity or wind speed. This same idea could be expanded to create dynamic maps of human-caused environmental parameters, such as traffic density.

To that end, the DYNAMAP monitoring stations should be equipped with additional environmental sensors capable of measuring the environmental parameters of interest. On the other hand, the open architecture of the DYNAMAP system will allow the easy integration of the new sensors (and of any data processing algorithms involved).

Investigation about possible future upgrades of the DYNAMAP system is undertaken in three tasks. The first of these tasks is devoted to hardware aspects, i.e. those related to how the DYNAMAP system should physically communicate with external devices (such as cameras, Bluetooth signal detectors or other types of sensors), including the study of standard communication protocols that would allow extending the hardware capabilities of the system.

The second task is focused on the upgrade of the anomalous noise event detection (ANED) algorithm that is in charge of filtering out those acoustic events not caused by road traffic that could alter the noise levels displayed in the real time maps. Thanks to the inclusion of additional sensors, it could be possible to correlate noise measures and other sensed parameters (e.g. Bluetooth signals). By doing so, the system would have more information to determine whether a set of high noise values are due to actual anomalous events rather than to higher traffic density.

And the third task is devoted to the study of the upgrade of the DYNAMAP system software as regards the creation and publication of dynamic maps referred to additional environmental parameters, including the management of the access to the new environmental data sets.

The main difficulties associated to the upgrade of the DYNAMAP system with additional environmental sensors are related with sensors technology. Due to the fast evolution of hardware, it may be difficult to foresee which should be the way to interface the DYNAMAP system with hypothetical added sensors. For this reason, in order to avoid future restrictions and reduce the probability of incompatibility between the DYNAMAP system and sensors that could be added to the monitoring stations in the future, sensors front-end will be considered as part of the sensors themselves. In this way, the system will operate as an open structure where sensors output will be treated just as simple electrical signals, making the system easily adaptable to a wide range of devices. As for the software side, future compatibility is foreseen to be much easier because name, range and calibration of sensors are just customized fields of the sensors database, so that data management is not envisaged to be a real problem.

As a result of this study, the potential of future upgrade of the DYNAMAP system will be clear.

4.2 Traffic management and control based on information retrieved from sensors

Road traffic noise is highly correlated with traffic density and activity. For this reason, it is sensible to envision the DYNAMAP system in the future as a source of valuable information about the status of traffic in the monitored areas. Definitely, this feature could boost the interest of authorities and general public in the DYNAMAP system, as traffic is one of the most complex factors that authorities must manage in urban and suburban environments, besides affecting citizens' quality of life to a large extent.

Clearly, having a real time map of traffic noise allows the development of multiple mitigating, short-term corrective and informative applications. The mitigating applications of the system are related to long term measures, and are of main interest to authorities. Based on the data acquired by the DYNAMAP system, the most critical areas in terms of noise and atmospheric pollution can be identified. Thus, action plans to mitigate the noise impact on people who live and work in those areas can be effectively addressed, such as the construction of acoustic barriers and low-noise pavements, the planting of trees to compensate for air pollutants, traffic calming policies and ITS systems for controlling and managing vehicles speed and traffic flow in real time could be efficiently designed thanks to the data provided by the DYNAMAP system.

The detection of high traffic noise levels in certain areas at a specific moment can be used with short term corrective and informative purposes, which can be of interest to both authorities and to general public. An example of this includes the development of an early warning system based on the interconnection between the DYNAMAP system and electronic roadside informative boards, which can be used to inform drivers of alternative routes, or to display traffic related messages.

The investigations in these directions will be undertaken in four tasks. The first of these tasks deals with the identification of possible future applications of the DYNAMAP system. To that end, the structure, periodicity and reliability of the data gathered by the system will be firstly analyzed to put forward realistic applications that are compatible with the hardware and software features of the system.

The second and third tasks are focused on evaluating the feasibility of the previously proposed application in terms of the hardware and software capabilities of the DYNAMAP system.

And the fourth and final task will compile the outcomes of the previous tasks to describe a series of feasible future applications of the DYNAMAP system related to traffic information and management.

5. Conclusions

The main aim and outcome of the Dynamap project is the provision of dynamic noise maps able to detect and represent in real time the acoustic climate of road infrastructures. Although such an appealing objective, the success of the DYNAMAP project is tied up to a series of basic secondary aspects that could boost or alienate its implementation on a large scale, such as costs and benefits, public response and user ability in consulting and managing the system, future development and exploitation of the system applications.

To prove and test the Dynamap system real implementation potential and economic sustainability, the project foresees a dedicated action where costs and benefits will be accurately analyzed and compared to those associated to traditional noise mapping activities. It is expected that providing updated information on the acoustic climate of road infrastructures (at any place and time) could lead to a significant reduction in noise mapping costs and offers perceptible benefits.

Another aspect that could drive the success of the project is linked to the ability of providing effective tools to manage the system and inform the public about noise issues. The tools should be able to read data coming from the system and depict noise values as colored geo-referred noise maps to be published on the system's web site in a user-friendly format. To improve the software application communication features, the project foresees an iterative process where users' ability in accessing information and managing the system will be checked through a series of tests.

This application will be also prepared to plot other environmental information in addition to noise maps, so as to yeld an integrated and comprehensive overview of road infrastructure impact, such as the volumetric concentration of pollutant agents in the atmosphere and weather indicators, thus providing a visual and constantly updated map of air quality and meteorological conditions. Based on the data acquired by the system, the most critical areas in terms of noise and atmospheric pollution can be identified, so that appropriate action plans to mitigate the noise impact on people who live and work in those areas can be effectively addressed.

Finally, the interest towards the project and its exploitation on a large scale could also be determined by the possibility in the future of linking the Dynamap system to intelligent transportation systems (ITS), thus contributing to reduce vehicles noise emissions through the control and management of the traffic flow. Also this issue, like the other above mentioned aspects, will be accurately analyzed in a dedicated action on future development applications.

ACKNOWLEDGMENTS

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3 *Council Directive 90/313/EECof 7 June 1990 on the freedom of access to information on the environment*, Official Journal L 158 , 23/06/1990 P. 0056 - 0058, (1990).

4 *END Directive 2002/49/EC of the European parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise*, Official Journal of the European Communities, L 189/12, (2002).

5 CEDR Project Group Road Noise - Subgroup Noise Action Plans, *National Road Authorities Practice and Experiences*, Report(2013).

6 Harmonica, available: http://www.noiseineu.eu.

APPENDIX 2 - Dynamap special session presentations

THE LIFE DYNAMAP PROJECT: TOWARDS THE FUTURE OF REAL TIME NOISE MAPPING
Patrizia Bellucci

STATE OF THE ART ON REAL TIME NOISE MAPPING SYSTEM AND RELATED SOFTWARE DEVELOPMENT
Andrea Cerniglia

THE LIFE DYNAMAP PROJECT: AUTOMATING THE PROCESS FOR PILOT AREAS LOCATION
Simone Radaelli, Annalisa Giovannetti

DYNAMAP: SENSITIVITY ANALYSIS OF THE ACOUSTIC CALCULATION MODEL WITH RESPECT TO ENVIRONMENTAL VARIABLES INSIDE AND OUTSIDE URBAN AREAS
Alessandro Bisceglie

TRAFFIC NOISE MONITORING IN THE CITY OF MILAN: CONSTRUCTION OF A REPRESENTATIVE STATISTICAL COLLECTION OF ACOUSTIC TRENDS
Fabio Angelini

DEVELOPMENT OF OPTIMIZED ALGORITHMS FOR THE CLASSIFICATION OF NETWORKS OF ROAD STRETCHES INTO HOMOGENEOUS CLUSTERS IN URBAN AREAS
Giovanni Zambon

DYNAMAP MONITORING NETWORK HARDWARE DEVELOPMENT
Luca Nencini

DEVELOPMENT OF AN ANOMALOUS NOISE EVENT DETECTION ALGORITHM FOR DYNAMIC ROAD TRAFFIC NOISE MAPPING
Joan Claudi Socoró

BASIC SECONDARY ASPECTS OF THE LIFE DYNAMAP PROJECT
Laura Peruzzi

WHAT CITIES COULD DESIRE FROM DYNAMAPS
Henk Wolfert

DYNAMAP FROM THE POINT OF VIEW OF REGIONE LOMBARDIA
Pietro Lucia

HARMONICA PROJECT
Piotr Gaudibert

DYNAMAP
Dynamic Acoustic Mapping

T05.SS02

DYNAMAP SPECIAL SESSION I

16 JULY 2015

DYNAMAP
Dynamic Acoustic Mapping

T05.SS02

DYNAMAP SPECIAL SESSION I

16 JULY 2015

Room R05

Programme

08:00 THE LIFE DYNAMAP PROJECT: TOWARDS THE FUTURE OF REAL TIME NOISE MAPPING
Patrizia Bellucci

08:20 STATE OF ART ON REAL TIME NOISE MAPPING SYSTEM AND RELATED SOFTWARE DEVELOPMENT
Andrea Cerniglia

08:40 THE LIFE DYNAMAP PROJECT: AUTOMATING THE PROCESS FOR PILOT AREAS LOCATION
Simone Radaelli, Annalisa Giovannetti

09:00 DYNAMAP: SENSITIVITY ANALYSIS OF THE ACOUSTIC CALCULATION MODEL WITH RESPECT TO ENVIRONMENTAL VARIABLES INSIDE AND OUTSIDE URBAN AREAS
Alessandro Bisceglie

09:20 TRAFFIC NOISE MONITORING IN THE CITY OF MILAN: CONSTRUCTION OF A REPRESENTATIVE STATISTICAL COLLECTION OF ACOUSTIC TRENDS
Fabio Angelini

09:40 DEVELOPMENT OF OPTIMIZED ALGORITHMS FOR THE CLASSIFICATION OF NETWORKS OF ROAD STRETCHES INTO HOMOGENEOUS CLUSTERS IN URBAN AREAS
Giovanni Zambon

10:00 Coffee Break
10:20 PLENARY LECTURE
Semyung Wang

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

T05.SS02
DYNAMAP SPECIAL SESSION I
16 JULY 2015
Room R05

11:20 DYNAMAP MONITORING NETWORK HARDWARE DEVELOPMENT
Luca Nencini
11:40 DEVELOPMENT OF AN ANOMALOUS NOISE EVENT DETECTION ALGORITHM FOR DYNAMIC ROAD TRAFFIC NOISE MAPPING
Joan Claudi Socoró
12:00 BASIC SECONDARY ASPECTS OF THE LIFE DYNAMAP PROJECT
Laura Peruzzi

12:20 Panel Discussion

Stakeholders' desiderata – *What stakeholders would like dynamic maps should do.*
The perspective of Eurocities (Henk Wolfert) and Lombardia Region (Pietro Lucia)

Why dynamic noise maps?- *The benefits and drawbacks of being informed in real time*.
The experience of Harmonica (Piotr Gaudibert)

Final remarks and suggestions (*Gaetano Licitra – ARPAT)*

13:00 End of the Session

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

THE LIFE DYNAMAP PROJECT Towards the future of real-time noise mapping

P.Bellucci[1], L. Peruzzi[1], G. Zambon[2]

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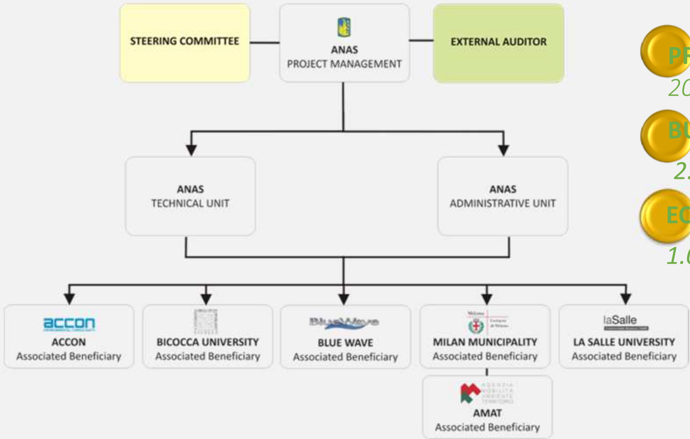
22nd International Conference on Sound and Vibration
Florence 12-16 July 2015

WHAT IS THE DYNAMAP PROJECT ?



PROJECT SPAN
2014-2019

BUDGET
2.230.319 €

EC CONTRIBUTION
1.063.274 € (48%)

WHY THE DYNAMAP PROJECT ?

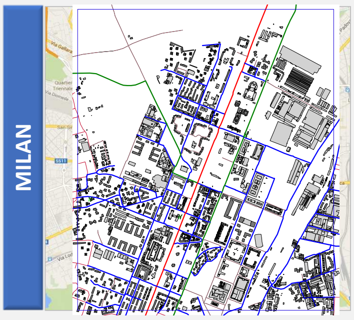
Directive 2002/49/EC

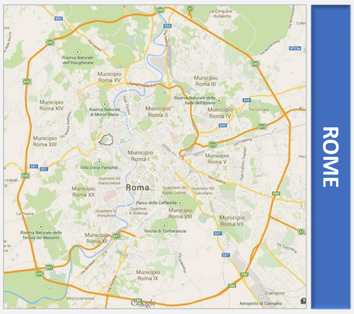
…Aim of the Directive is to define a common approach intended to avoid, prevent or reduce the harmful effects due to exposure to environmental noise. To that end, noise maps must be provided and updated every five years in order to report about changes in environmental conditions that may have occurred over the reference period…

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

PROJECT OBJECTIVES

The main objective is **to reduce the cost** of the noise mapping process through the development of a low cost sensors system able to **automatically update** the noise maps in real time.





DYNAMAP
DYNAMIC ACOUSTIC MAPPING

PROJECT OBJECTIVES

- The main objective is **to reduce the cost** of the noise mapping process through the development of a low cost sensors system able to **automatically update** the noise maps in real time.
- As a secondary objective, the project aims at demonstrating that dynamic mapping can be also applied **to monitor and report the information related to other environmental parameters**, such as those related to air quality, meteorological conditions, traffic, etc.
- Finally, the Dynamap system will be also equipped with a GIS web software application for **public information and communication** on noise issues.

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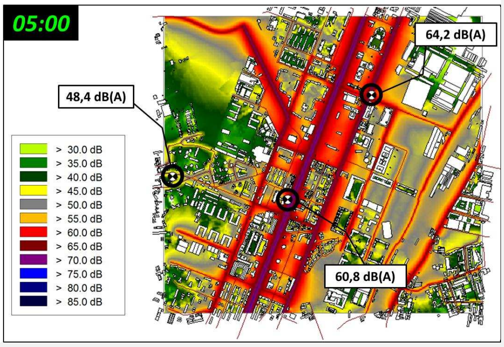
THE PROJECT IDEA

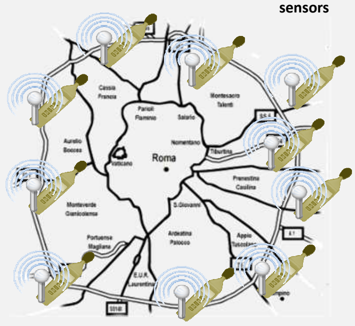
Low cost SLM



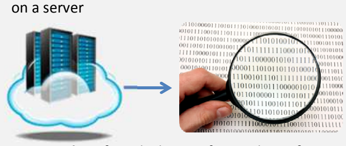
GIS BASED APPLICATION

THE DYNAMAP SYSTEM

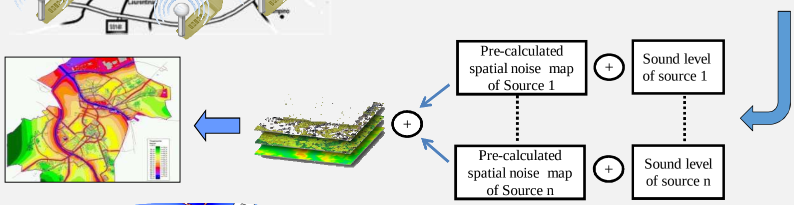
Wireless noise sensors



Data collection. Data sent from the sensors are archived on a server



Data analysis for calculation of Leq values of specific sources:
1 - Identification and removal of spurious events
2 - Calculation of sound level on a defined time basis



DYNAMAP
Dynamic Acoustic Mapping

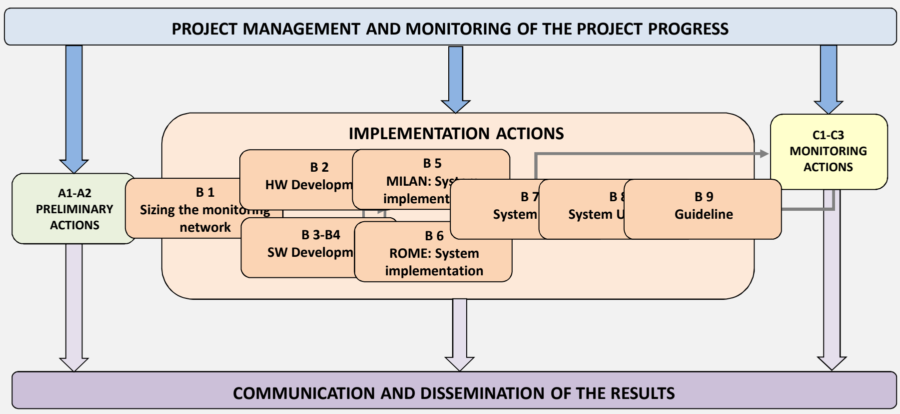
MAIN STEPS OF THE PROJECT

The project will be accomplished through four main steps:

1. Development of low cost sensors and tools for the management of real time noise maps on a GIS platform.
2. Design and implementation of two demonstrative systems in the cities of Milan and Rome.
3. Systems monitoring for at least one year to check criticalities, analyze problems and faults that might occur over the test period.
4. Provision of a guideline for the design and implementation of real time noise mapping.

DYNAMAP
Dynamic Acoustic Mapping

MAIN ACTIONS



ADDED VALUE

- Potential reduction of the financial effort required to provide the update of noise maps. **50% of cost reduction** is expected.
- Automation of the noise mapping process. Consistent time reduction for the update of noise maps.
- Smart applications for public information and communication.
- Connection of the Dynamap system to ITS systems to smooth traffic and reduce noise. **2-3 dB(A) of noise reduction** is expected.

EXPECTED BENEFITS

- a real time update of noise maps as a consequence of the mapping process automation;
- a reduction of the sites to be noise mapped with traditional tools and expensive monitoring campaigns to collect input data;
- a faster response to noise mitigation requests, thanks to the real time availability of updated dynamic maps;
- a more comprehensive and reliable information on the environmental impact due to traffic.

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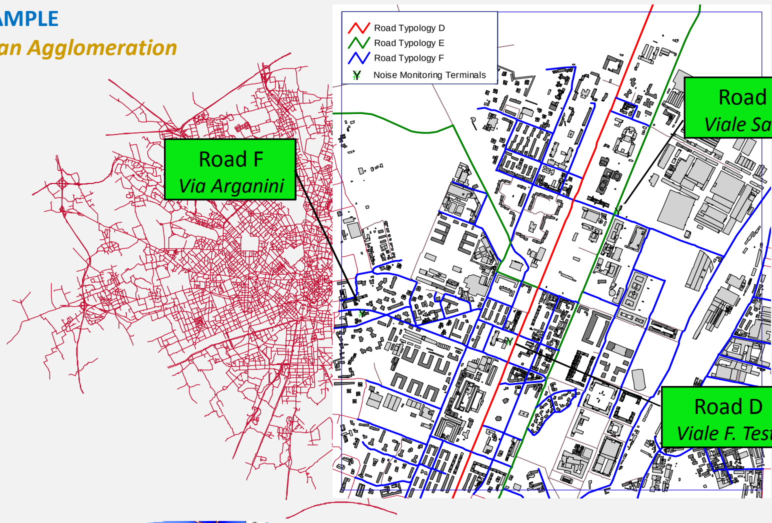
EXAMPLE
Milan Agglomeration



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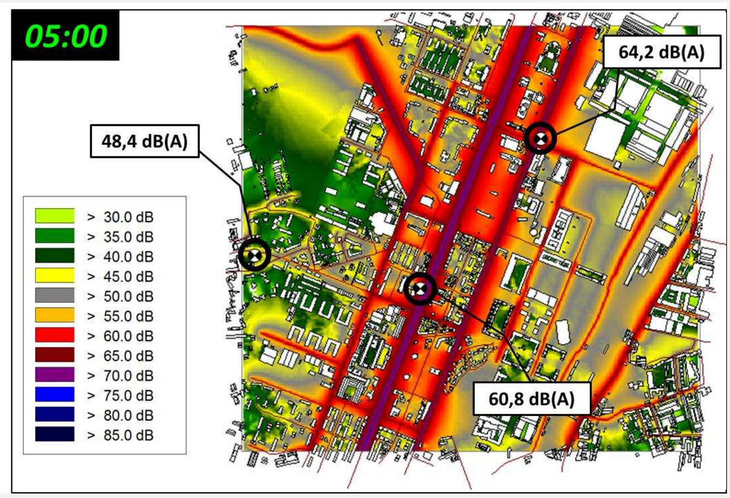

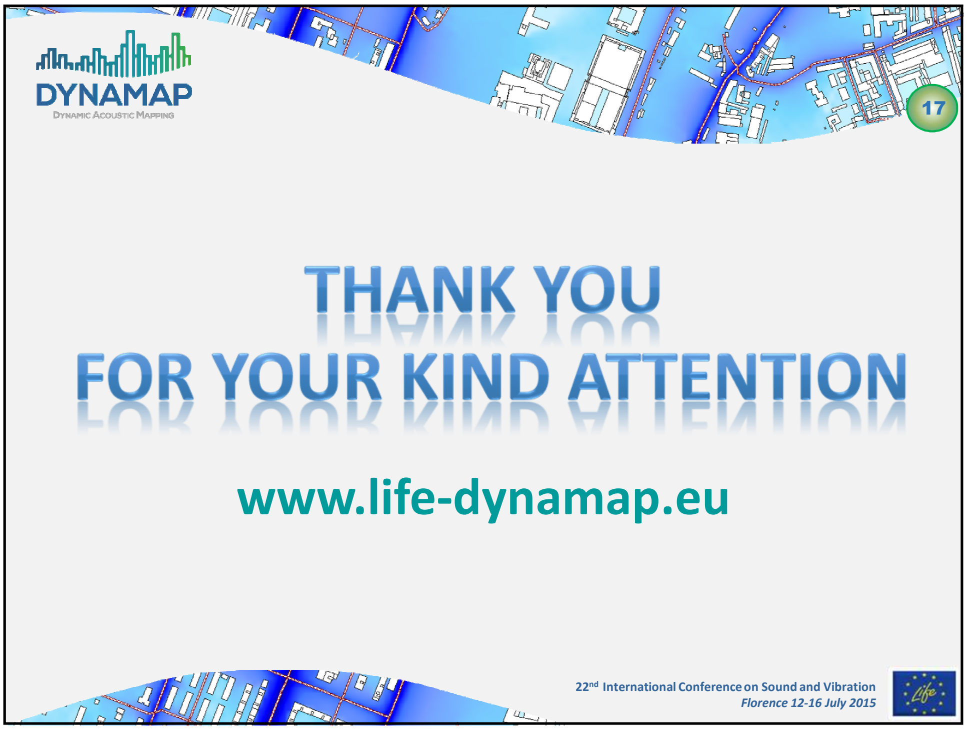
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State of the art on real time noise mapping system and related software development

Andrea Cerniglia

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Exposure of cityzens to noise is a widely recognized problem which also involves important social cost for health

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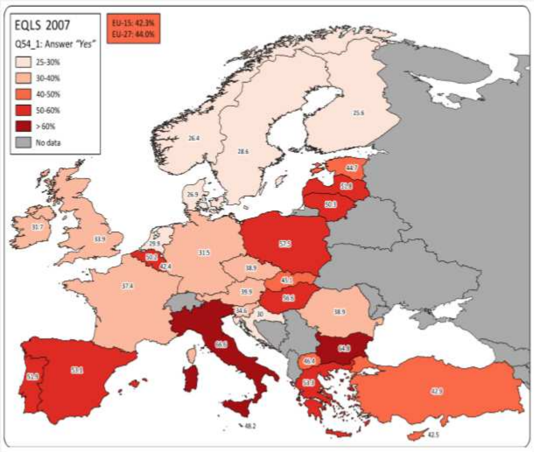

Noise compliant Europe map

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2009/49/CE (END) asks for update noise maps

every 5 years

Real Time Noise Mapping can be an effective and cheap tool to satisfy END requirments and to ‘create’ a kind of ‘*acoustic consciousness’* in citizens

Dynamap Action A1

State of the art on dynamic noise mapping

7

Principle of operation for Real Time Noise Mapping

8

Principle of operation :

a) Measure
b) Compute
c) Publish

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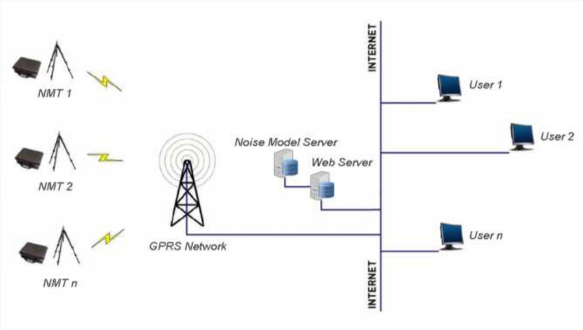
Principle of operation :



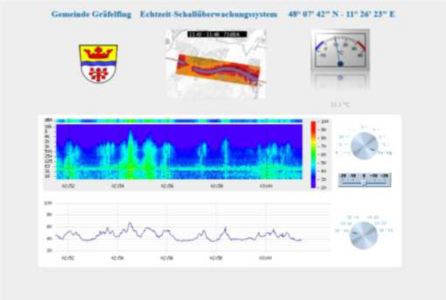
Some existing systems are already available

Implemented or Name	Type
ACCON	Scaling and sum of pre-computed maps
Datakustik	Scaling and sum of pre-computed maps
Gdansk University	On-line calculation
GEIART	Cluster analysis on traffic model
Ghent	Simplified calculation
IDASC CNR	Scaling of pre-computed maps
Laermometer	Citizens contributive mobile noise mapping (smartphone)
NoiseMote	Low cost sensor system, no mapping
NoiseTube	Citizens contributive mobile noise mapping (smartphone)
SADMAM	Scaling and sum of pre-computed maps

Analysys of existing softwares showed three main approaches:

- On-line calculation (simplified or optimized)
- Citizens contributive mapping
- Scaling and sum of pre computed maps

Accon approach:

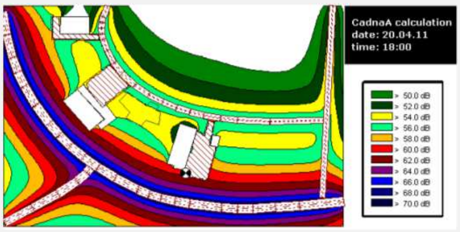


Accon approach:

- Standard noise monitoring station
- Single point measurement
- Publishing of relevant map, according to measured value

System is working since 2009 at http://graefelfing.noisemonitoring.de

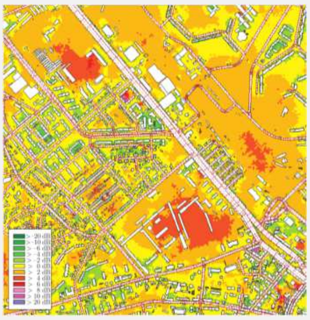
Datakustik approach:



Datakustik approach:

- Standard noise monitoring station
- Multi points measurement
- Scale and sum by means of noise model software

Gdansk Univerity approach:



Gdansk Univerity approach:

- Standard noise monitoring station
- On-line calculation
- (with 2032 cores, 48 hours are needed for 256km^2 area)
- Publishing of computed map

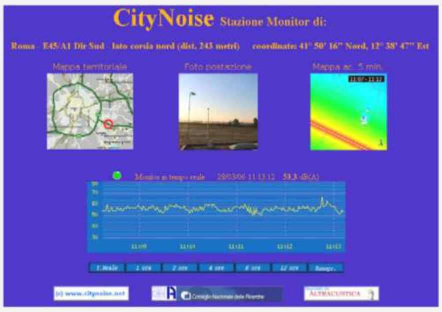
GEIART approach:

- traffic flow measurement + cluster analysis
- Calculation a publishing (just research, never implemented)

GHENT University approach:

- Standard noise monitoring stations
- Simplified calculation (direct, reflected, diffracted, scattered)
- Publishing

IDASC approach:



IDASC approach:

- Standard noise monitoring stations
- Single point measurement
- Publishing of relevant map, according to measured value

Learmometer approach:

Learmometer approach:

Cityzens contributive (mobile phones)

Spot random measurements

No map

Noisemote approach:

Noisemote approach:

- Low cost monitoring stations
- Fixed measurements
- No map

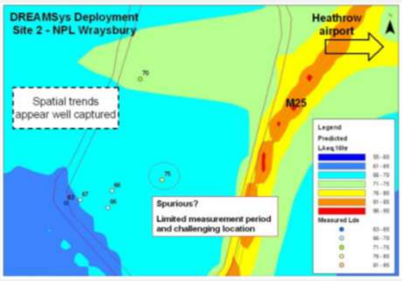
NoiseTube approach:

NoiseTube approach:

- Cityzens contributive (mobile phones)
- Spot random measurements
- No map

System worked from 2006 til 2012

NPL approach:



NPL approach:

- Low cost sensors (dreamsys)
- Fixed measurements

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SADMAM approach:

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SADMAM approach:

- Standard noise monitoring station
- Publishing of scaled noise maps by means of noise pred. software

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Position of Dynamap project

Investigation showed that Dynamap approach merge the best characteristics of all the investigated previous approaches, and, at the same time, tries to minimize specific disadvantages like monitoring equipment costs, needs of running noise model, need of powerful cluster computing, etcetera.

Thanks for your attention

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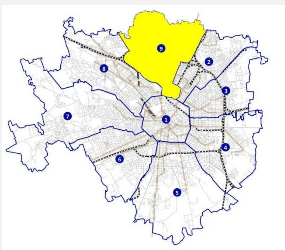
THE LIFE DYNAMAP PROJECT: AUTOMATING THE PROCESS FOR PILOT AREAS LOCATION

S. Radaelli, P. Coppi (AMAT S.r.l.)
A. Giovannetti, R. Grecco (ANAS S.p.A.)

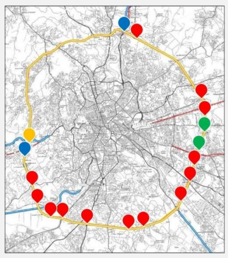
INTRODUCTION

The identification of the pilot areas is one of the ***Preparatory actions*** of the Dynamap Project. The methodology for pilot areas location was developed differently in the two contexts in which the dynamic noise maps will be tested . The application of the methods developed led to the identification of a single pilot area for the agglomeration of Milan and 17 test sites for the major road around Rome.

Pilot area of Milan



Pilot areas of A90 Motorway - Rome



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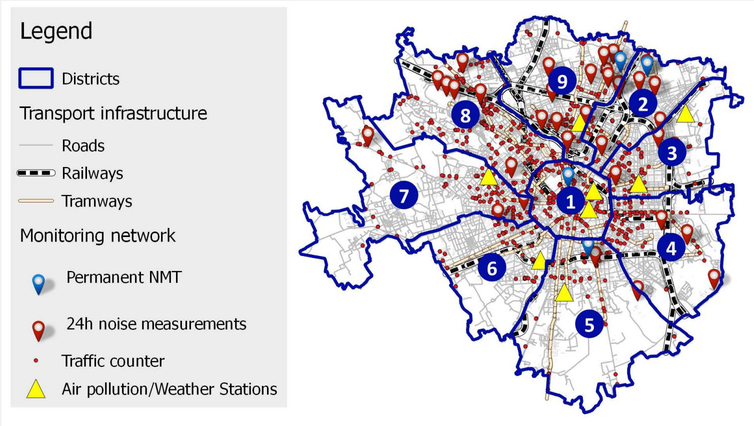
PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- Data collection -



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PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- Data collection -

Layer	Description
Road network	Road graph (shapefile). It contains arc lenghts, mean daily traffic, functional class (PGTU)
Railways	Railway graph used to calculate the length of the network
Tramways	Tramway graph used to calculate the length of the network
Residential Buildings	Polygonal shapefile containing data about population, noise level exposure and limit values. Data come from the strategic noise map
Noise Monitoring Stations	Point shapefile containing information on measure type and instrument typology (fixed or temporary noise stations)
Traffic Monitoring Stations	Point shapefile including data on road traffic retrieved from counting devices
OpenWifi Access Points	Text file regarding open wifi access point

PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- Variable list, score assignment criteria and weights (1/2) -

Variable category	Variable	Score assignment criterion	Weight (c)
Territory	Area [km^2]	Sort descending	**0,25**
	Number of citizens [n]		**0,50**
	Linear road length [km]		**0,25**
Road traffic	Urban traffic plan (PGTU) class distribution [n]	Sort descending	**1,00**
	Average daily traffic (ADT) [n]		**0,50**
Acoustic data	Population exposed to L_{den} > 70 dB(A) [n]	Sort descending	**1,00**
	Pop. exp. to noise levels > limit for nightime [n]		**1,00**
	Number of measures (> 24h) [n]		**1,00**

PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- Variable list, score assignment criteria and weights (2/2) -

Variable category	Variable	Score assignment criterion	Weight (c)
Noise monitoring	Noise monitoring terminal(NMT) [n]	6 pts/terminal	**1,00**
Non acoustic data monitoring	Road traffic monitoring stations [n]	Sort descending	**1,00**
	Air quality/weather stations [n]	3 pts/station	**1,00**
Other sources	Railway length [km]	Sort ascending	**0,50**
	Tramway lenght [km]		**0,50**
Data transmission	OpenWifi access points [n]	Sort descending	**1,00**

PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- Method of scoring -

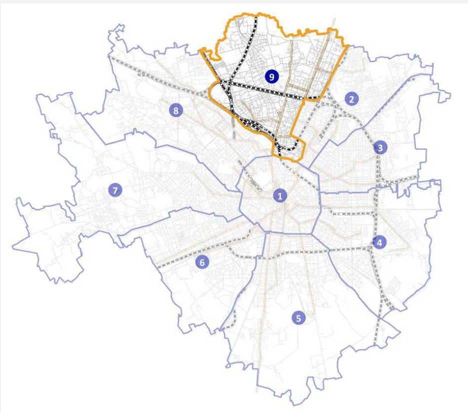
A. A score ranging **from 1 to 9** is given to districts for each variable category as a **function of their position on the ranking list**, achieved by combining the figures related to the variables included in the category. Districts are sorted ascending or descending depending on the variable category.

B. A **fixed score of 3 points** is assigned for each **air quality/weather station** present in the area; likewise a **6 points** score is allocated for each **noise monitoring terminal**.

The scores assigned to variables are then weighted using the coefficients previously depicted. The total score of each zone is finally obtained by adding the resulting values. In the end, the ranking list is achieved sorting the scores associated to the district zones.

PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- Ranking list -

RANK	POINTS	DISTRICT ID
1	58,25	9
2	58,00	8
3	52,25	7
4	47,25	2
5	46,00	5
6	45,25	4
7	42,00	1
8	41,25	3
9	40,25	6



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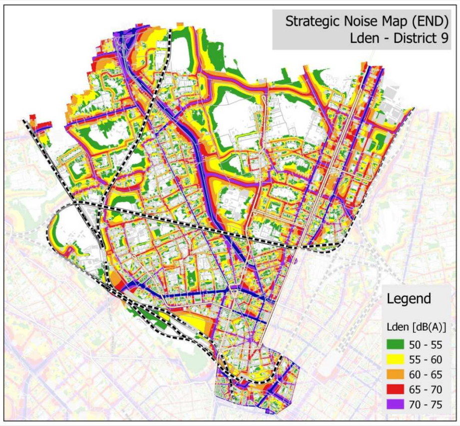
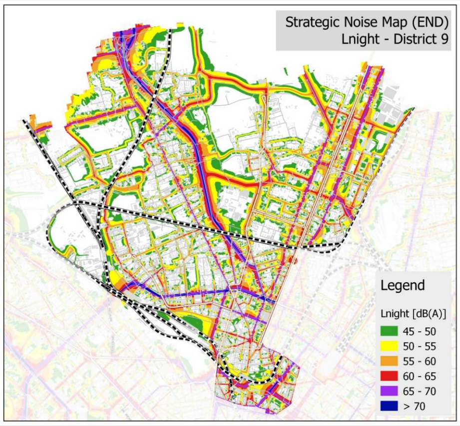
PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- District 9 -





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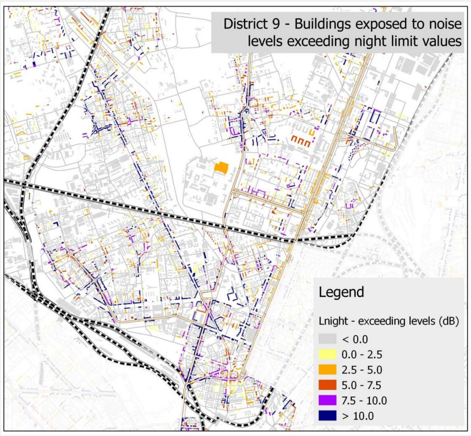
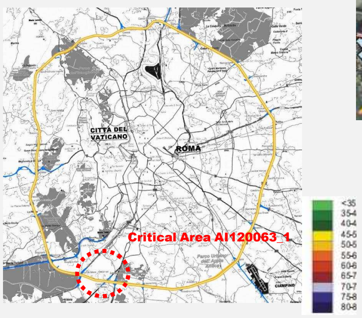
PILOT AREA LOCATION FOR URBAN CONTEXT (MILAN)
- District 9 -

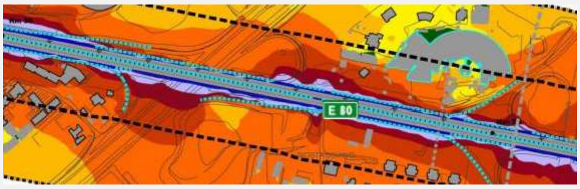


PILOT AREA 2 - SUBURBAN CONTEXT Critical Area AI120063_1

Pilot areas of A90 Motorway - Rome



Areal View



Noise Map Leq Day

SELECTION OF THE TEST SITES (ROME)

For the selection process of the test sites,
the following informations were taken into account

Layer	Description
Road Network	Road graph. It contains the arcs belonging to the A90 motorway.
Other Roads (ASA)	Road graph. It contains the arcs related to roads running parallel or crossing the A90 motorway, belonging to ANAS, within a buffer wide each side of the motorway axis.
Railways (FS)	Graph of the railways running parallel or crossing the A90 motorway within a Buffer wide each side of the motorway axis, identified and included in the Action Plan.
Critical Areas (CA)	In the contains the areas where noise limits values are exceeded, retrieved from ANAS Action Plan.
Variable Message Panels (PMV)	Point layer reporting information on the location of Variable Message Panels.
Traffic Couting Devices (TC)	Point layer related to the position were traffic monitoring devices are installed.
Switchboard (PMV_Quadri)	Point layer reporting information on the position of the switchboards along the motorway.

DESCRIPTION OF THE TOOL (ROME)

The tool was implemented in a GIS environment, using the Arcinfo "Model Builder", through an algorithm based on the following five steps:

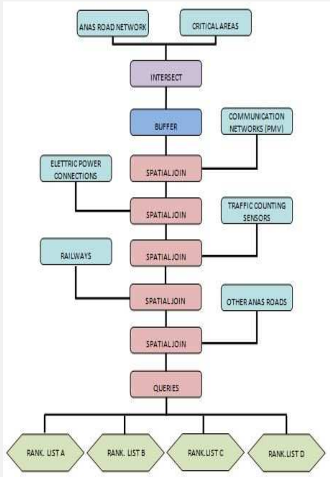
Step 1: Preparation of the pilot area

Step 2: Filtering of critical areas missing connection to the power grid and communication channels

Step 3: Selection of critical areas with traffic counting devices

Step 4: Identification of critical areas with additional noise sources

Step 5: Sites classification



SELECTION CRITERIA

SCENARIO A
Single road (A90Motorway)

SCENARIO B
Two crossing or parallel roads

SCENARIO C
Crossing or parallel railway line

SCENARIO D
Complex scenarios

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CRITICAL AREAS SELECTION

Single road: this list consists of areas with the mere presence of the primary source (A90 Motorway). Twelve areas, in order of decreasing priority, have been chosen to host the DYNAMAP sensors.

RANKING LIST A - SINGLE ROAD CRITICAL AREAS													
LOCALIZATION			ACOUSTIC FEATURES								TRAFFIC FEAUTERS		
Area Code	Start (km)	End (km)	Priority Index	Number of residents	N. of people exposed to noise	N. of buildings exposed to noise	Exceeded noise limits Day (dBA)	Exceeded noise limits Night (dBA)	Presence of other roads	Presence of railways	ADT (vehic/24h)	AVERAGE HOURLY TRAFFIC Day (vehic/h)	AVERAGE HOURLY TRAFFIC Night (vehic/h)
AI120051	34+450	35+665	135909,5	9416	14806	12 Residential 3 Sensitive	0-12	>12	NO	NO	62584	3498	827
AI120063	48+936	49+212	5483,6	3854	1513	13 Residential	0-6	0-12	NO	NO	67688	3803	855
AI120016	64+528	64+720	4716,8	1347	389	2 Residential 1 Sensitive	_ _ _	0-3	NO	NO	40288	2452	132
AI120049	34+450	35+665	3858,9	4096	973	28 Residential	_ _ _	0-9	NO	NO	69488	3879	928
AI120045	23+192	24+028	3020	3426	1159	22 Residential 1 Sensitive	0-12	0-9	NO	NO	69776	3913	896
AI120054	41+809	42+628	2996,1	1027	3569	14 Residential	_ _ _	0-6	NO	NO	62584	3498	827
AI120057	47+604	48+617	814,4	1171	737	41 Residential	0-3	0-9	NO	NO	67688	3803	855
AI120028	63+151	63+289	426,8	140	140	2 Residential	_ _ _	0-6	NO	NO	67668	3803	855
AI120058	48+936	49+212	169,5	182	94	7 Residential	_ _ _	0-3	NO	NO	67688	3803	855
AI120053	41+203	41+303	58	621	29	1 Residential	_ _ _	0-3	NO	NO	62584	3498	827
AI120029	64+528	64+720	57,9	334	209	7 Residential	_ _ _	0-3	NO	NO	67668	3803	855
AI120066	57+749	57+849	0,4	4	4	1 Residential	_ _ _	0-3	NO	NO	67688	3803	855

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CRITICAL AREAS SELECTION

Additional crossing or parallel roads: this list includes areas with other crossing or parallel roads belonging to ANAS road network. Only one critical area complying with such requirements was found (SS1 Aurelia).

RANKING LIST B - CRITICAL AREAS WITH ADDITIONAL CROSSING OR PARALLEL ROADS													
LOCALIZATION			ACOUSTIC FEATURES								TRAFFIC FEAUTERS		
Area Code	Start (km)	End (km)	Priority Index	Number of residents	N. of people exposed to noise	N. of buildings exposed to noise	Exceeded noise limits Day (dBA)	Exceeded noise limits Night (dBA)	Presence of other roads	Presence of railways	ADT (vehic/24h)	AVERAGE HOURLY TRAFFIC Day (vehic/h)	AVERAGE HOURLY TRAFFIC Night (vehic/h)
AI120034	0+000	0+350	366,7	236	94	10 Residential	0-9	0-12	SS1 Aurelia	NO	40288	2452	132

CRITICAL AREAS SELECTION

Railway lines running parallel or crossing the A90 motorway: to this category belong those sites where railways are running parallel or crossing the A90 motorway. Two sites were found to be compliant with the specifications.

RANKING LIST C - CRITICAL AREAS WITH RAILWAY LINES RUNNING PARALLEL OR CROSSING THE A90 MOTORWAY													
LOCALIZATION			ACOUSTIC FEATURES								TRAFFIC FEAUTERS		
												AVERAGE HOURLY TRAFFIC	
Area Code	Start (km)	End (km)	Priority Index	Number of residents	N. of people exposed to noise	N. of buildings exposed to noise	Exceeded noise limits Day (dBA)	Exceeded noise limits Night (dBA)	Presence of other roads	Presence of railways	ADT (vehic/24h)	Day (vehic/h)	Night (vehic/h)
AI120048	31+549	33+451	12225,1	7554	3140	65 Residential 4 Sensitive	0-9	>12	NO	Roma-Pescara	69488	3879	928
AI120050	37+986	39+172	7148,6	8582	2496	40 Residential	0-6	0-12	NO	Roma-Pantano	62584	3498	827

CRITICAL AREAS SELECTION

Scenarios with multiple connection: includes two sites complying with the selection requirements.

RANKING LIST D - COMPLEX CRITICAL AREAS WITH MULTIPLE CONNECTIONS													
LOCALIZATION			ACOUSTIC FEATURES								TRAFFIC FEAUTERS		
												AVERAGE HOURLY TRAFFIC	
Area Code	Start (km)	End (km)	Priority Index	Number of residents	N. of people exposed to noise	N. of buildings exposed to noise	Exceeded noise limits Day (dBA)	Exceeded noise limits Night (dBA)	Presence of other roads	Presence of railways	ADT (vehic/24h)	Day (vehic/h)	Night (vehic/h)
AI120043	19+749	20+444	5934,7	3434	1301	15 Residential	0-6	0-9	SS4 Salaria	Roma-Firenze	69776	3913	896
AI120067	63+300	68+241	961,6	913	270	32 Residential	0-3	0-9	SS1 Aurelia	Pisa-Roma	67688	3803	855

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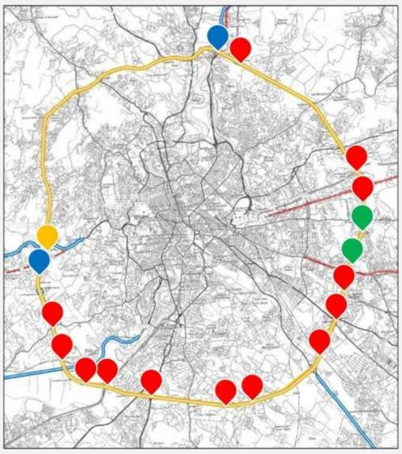
Pilot areas of A90 Motorway - Rome



Scenario A: single road

Scenario B: crossing or parallel roads

Scenario C: crossing or parallel railway line

Scenario D: complex scenarios

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SENSITIVITY ANALYSIS OF THE ACOUSTIC CALCULATION MODEL WITH RESPECT TO ENVIRONMENTAL VARIABLES INSIDE AND OUTSIDE URBAN AREAS

Alessandro Bisceglie, Giovanni Zambon, Simone Radaelli

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INTRODUCTION

Dynamic Noise Mapping

A **model** of pilot areas reproducing road sources and environment

Acoustic calculation software

- ✓ road sound power level
- ✓ environmental noise attenuation along each source-receiver propagation path

Noise maps

precalculated basic noise maps updated according to noise levels acquired by local low cost sensors

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SENSITIVITY ANALYSIS

Variation of **environmental conditions** → Noise levels variation

Some parameters of the calculation model will change → **New basic map,** independent from acquired acoustic data variation

The most significant parameters to be analyzed have been identified on the basis of the two environmental contexts investigated in the project (pilot areas):

Environmental context	Main parameter	Related simulation aspects
Extra-urban areas	meteorological conditions	long distance propagation
Urban areas	traffic conditions	noise source emission

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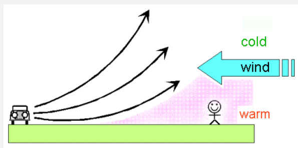
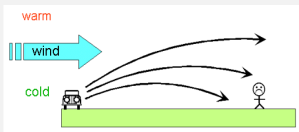
SENSITIVITY WITH RESPECT TO METEOROLOGICAL CONDITIONS

XPS 31-133 algorithm

homogeneous conditions
straight-line sound propagation, e.g. no-wind conditions



favourable to propagation conditions
the sound paths are refracted downwards, e.g. downwind conditions



Sound ray refraction induced by atmosphere layers determines a different persistence of the sound wave at the ground level

→ Influence of Ground Factor (G)

→ Influence of source height with respect to receiver height

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SENSITIVITY WITH RESPECT TO METEOROLOGICAL CONDITIONS

Set of acoustic simulations:

Constant parameters:

- **Sound source**: single line, Lw, geometric parameters, source length
- **Calculation parameters**: max search radius, order of reflection, etc.
- **Receiver points**: in line, at increasing distance from the source, every 10 m, up to 500 m distance; height of 4 meters on the ground

Variable parameters:	*n° scenarios*
• **Source height**: ground level road, road at higher level (2, 4, 6, 8, 10 meters)	6
• **Ground Factor** (G) values: 0.0 - 0.2 - 0.4 - 0.6 - 0.8 - 1.0	6
• **Meteorology**: homogeneous / favourable conditions	2

Total: 72 simulations

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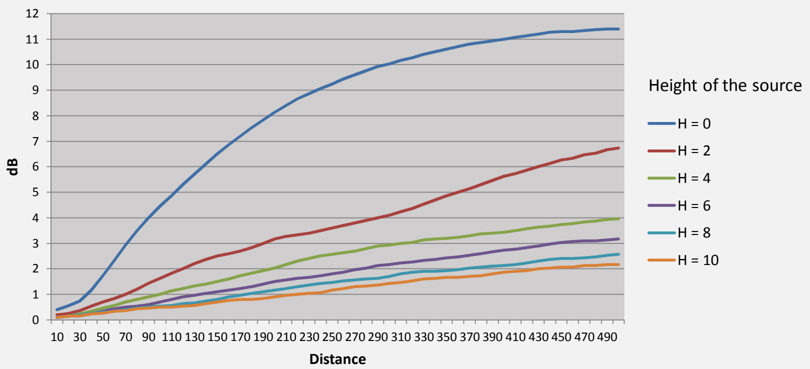
SENSITIVITY WITH RESPECT TO METEOROLOGICAL CONDITIONS

Δ Favourable-Homogeneous; G = 1,0



Difference between calculated noise levels in favourable and homogeneous atmospheric conditions

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DYNAMIC ACOUSTIC MAPPING

SENSITIVITY WITH RESPECT TO TRAFFIC CONDITIONS

Main elements related to the variability of traffic conditions:

Road network features
- ✓ crossroads/junctions
- ✓ traffic lights
- ✓ length of the road stretches

Temporal variablility
- ✓ short-time events
  traffic light duration
- ✓ long-time events
  peak or low traffic periods

Relevance: inside urban areas, complex road network

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

SENSITIVITY WITH RESPECT TO TRAFFIC CONDITIONS

XPS 31-133 algorithm → *Different «Traffic flow» conditions*

- ✓ **Continuous**
- ✓ **Interrupted**
- ✓ **Accelerated**
- ✓ **Decelerated**

→ **Road noise emission**
Lw'(dBA)

- average speed
- % heavy vehicles

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

SENSITIVITY WITH RESPECT TO TRAFFIC CONDITIONS

Set of acoustic simulations:

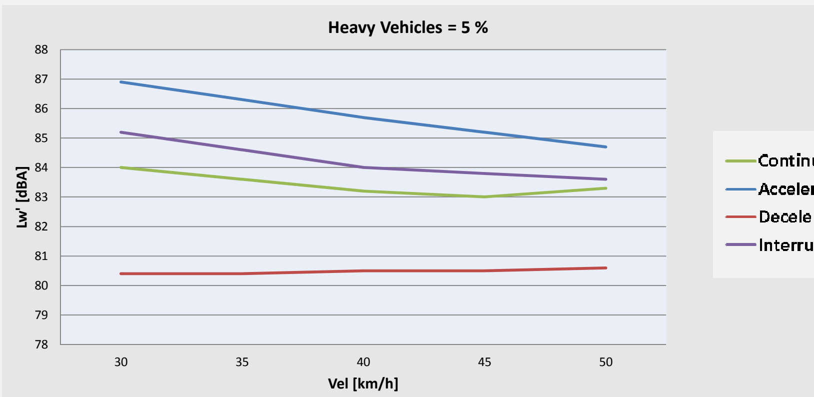
	Variable parameters		
	Var. 1	Var. 2	Var. 3
	Flow condition	***Speed (Km/h)***	***% Heavy vehicles***
values	continuous	30	0
	interrupted	35	1
	accelerated	40	2
	decelerated	45	3
		50	4
			5

Total number of LAw' calculations = 120

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

SENSITIVITY WITH RESPECT TO TRAFFIC CONDITIONS

Calculated sound power levels in different traffic flow conditions



SENSITIVITY WITH RESPECT TO TRAFFIC CONDITIONS

Two modeling approaches:

a) **Continuous** traffic conditions in each road segment

Speed value = urban speed limit

b) **Continuous** flow on the straight sections

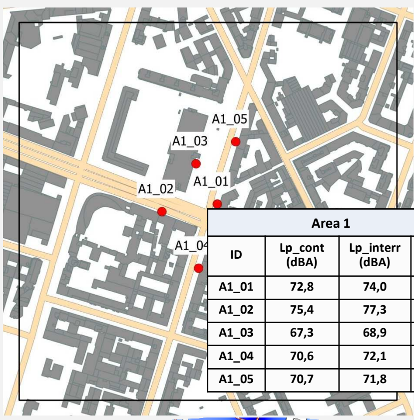
Interrupted traffic conditions in the 100 meter long road segments starting from the crossroad

Speed value = 30 km/h in interrupted condition

➡ *Application in two different urban contexts*

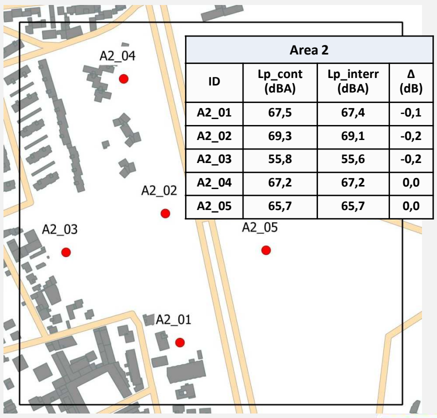
SENSITIVITY WITH RESPECT TO TRAFFIC CONDITIONS

Area 1: high density urban area, average speed = 50 km/h



Area 1			
ID	Lp_cont (dBA)	Lp_interr (dBA)	Δ (dB)
A1_01	72,8	74,0	1,2
A1_02	75,4	77,3	1,9
A1_03	67,3	68,9	1,6
A1_04	70,6	72,1	1,5
A1_05	70,7	71,8	1,1

Area 2: low building density, average speed = 70 km/h



Area 2			
ID	Lp_cont (dBA)	Lp_interr (dBA)	Δ (dB)
A2_01	67,5	67,4	-0,1
A2_02	69,3	69,1	-0,2
A2_03	55,8	55,6	-0,2
A2_04	67,2	67,2	0,0
A2_05	65,7	65,7	0,0

SENSITIVITY ANALYSIS OF THE CALCULATION ACOUSTIC MODEL

Conclusions:

49/2002 END: **Yearly average noise maps**	*Life+ DYNAMAP:* **Short-period dynamically updated noise maps**

1. **Meteorological conditions** — The results can guide the acquisition of local weather information required in the simulation process according to the different weather conditions settings and their relevance on noise levels calculation
2. **Traffic conditions** — Some possible approaches to modeling of traffic conditions in urban context have been suggested (e.g. strecth fragmentation near crossroads)

→ Several **basic noise maps** production

Thanks for your attention

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

TRAFFIC NOISE MONITORING IN THE CITY OF MILAN: CONSTRUCTION OF A REPRESENTATIVE STATISTICAL COLLECTION OF ACOUSTIC TRENDS

Zambon Giovanni, **Angelini Fabio**, Salvi Diego, Zanaboni Walter, Smiraglia Maura

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INTRODUCTION

ACTION B.1: Sizing the monitoring network

Aims:

Campaign of acoustic monitoring of road traffic noise in city of Milan

Collection of temporal trends of noise levels in order to create a statistically significant sample for post-processing analysis

Steps:

- collection and selection of previous noise data
- selection of monitoring sites based on specific criteria
- acquisition of the acoustic data
- correlation of acoustic data with weather data
- identification and deletion of abnormal events
- acquisition of series of equivalent sound levels
- storing data in a GEODATABASE

1. COLLECTION OF PREVIOUS ACOUSTICS DATA

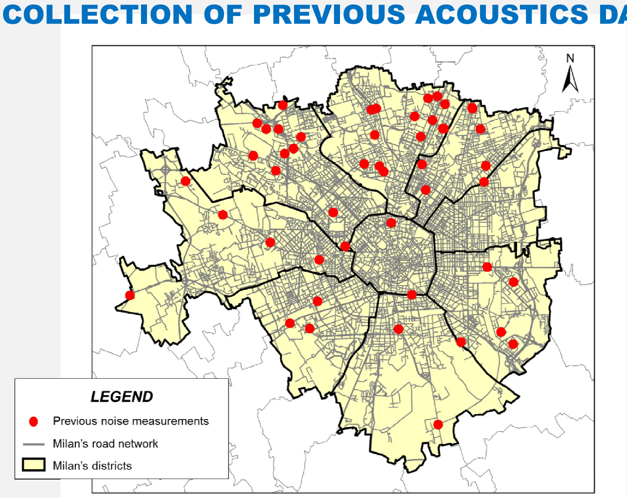
The first activity involved the archiving of previous noise measurements: from all the historical data available (measurements starting from 2009) only those specifically **related to road sources** and with a **minimum duration of 24 hours** were selected.

The collected data have different sources:

- **research purposes** by University of Milan – Bicocca
- **collaborative activities with institutions** such as the *Lombardy Region*, the *Municipality of Milan* and the *Milan Territory Environment Agency Mobility AMAT*

The dataset of previous continuous noise monitoring consists in **49 sites**, related to **8 different road categories**.

1. COLLECTION OF PREVIOUS ACOUSTICS DATA



2. EXECUTION OF A NOISE MONITORING CAMPAIGN

The second stage of the study involved the planning and execution of a new campaign of acoustic monitoring, closely related to the purposes of the project DYNAMAP.

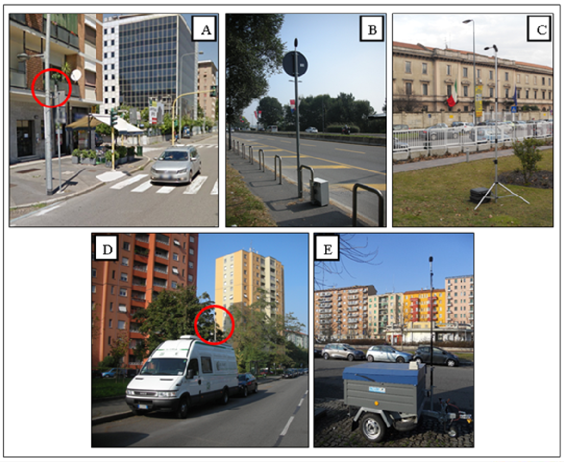
The monitoring activity's features:
- **minimum measurement time 24 hours**
- **start time at 6 a.m.**
- measurements protracted for **1 or more days**
- integration time **1 second**

General criteria to identify the measuring sites:
- uniform mapping of the entire metropolitan area
- noise sampling of different road categories (*A, D, E, F*) and road subcategories (*E 1-2, F 0-1-2-3*)
- various urban scenarios (urban canyons with different conformation, open sound field, etc.);
- different road surface type (asfalt, paved)
- different traffic flow types (fluid continuous, pulsed continuous, accelerated or decelerated)
- no influence of other roads on the monitored road stretch
- absence of other noise sources (tram lines, railways, airports, etc)

2. EXECUTION OF A NOISE MONITORING CAMPAIGN

Different types of monitoring units:

- fixed monitoring stations (A)
- semi-permanent monitoring stations (B-C)
- monitoring stations placed on cart or on mobile laboratory (D-E)



DYNAMAP
Dynamic Acoustic Mapping

3. PROCESSING OF THE MEASUREMENTS

All acquired data were elaborated in **3 STEPS**

STEP 1:

Sorting of noise data into different groups:

- **Weekdays**
- **Saturdays** *(analysis in progress)*
- **Sundays and public holidays** *(analysis in progress)*

STEP 2:

- correlation of the acoustic data with **weather data**
- noise data deletion when occur:

rainfall events ***(ARPA's method)*:**
precipitation > 2 mm: influential on individual hourly data
precipitation > 4 mm: influential on individual hourly data and that immediately following

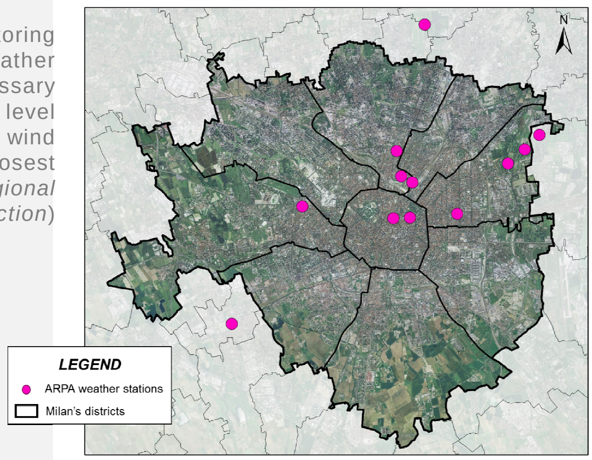
atmospheric turbulence events ***(Italian normative)*:**
wind speed > 5 m/sec: influential on individual hourly data

DYNAMAP
Dynamic Acoustic Mapping

3. PROCESSING OF THE MEASUREMENTS

STEP 2:

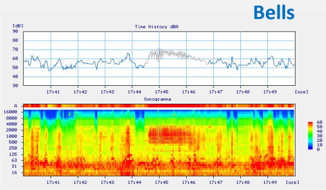
The units of acoustic monitoring weren't equipped with weather stations, therefore, it was necessary to associate every single noise level with weather data of rainfall and wind speed measured in the closest **weather station of ARPA** (*Regional Agency for Environmental Protection*) located on Municipality of Milan



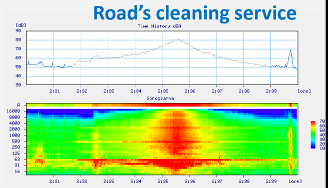
3. PROCESSING OF THE MEASUREMENTS

STEP 3:
Deletion of extraordinary or abnormal events such as *sirens, bells, airplane transits, noisy human activities, technical facilities*, because their presence can affect and alter the equivalent noise level. The identification of the extraordinary events was based on the comparison and analysis of the sonograms

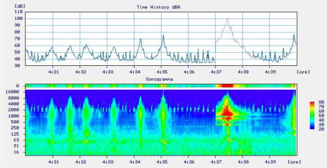
Bells



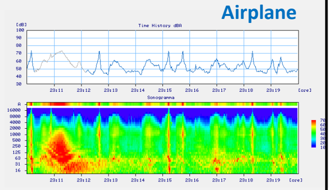
Road's cleaning service



Siren



Airplane



4. RESULTS OF NOISE MONITORING CAMPAIGNS

After the corrections of the acquired data, the sound pressure levels were calculating by integrating the acoustic data on **different time intervals**, respectively: **5, 10, 15, 20, 30 and 60 minutes.** Therefore each **dataset** contains **six noise trends at different time resolutions.** Every monitoring site is represented by one or more dataset.

The succession of equivalent noise levels on 24 hours represents a noise trend, which constitutes the basis for subsequent statistical analysis.

SITE	COD	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-24.00
Gattamelata	E5	*65,8*	*68,3*	*68,9*	*68,6*	*69,4*	*68,1*	*66,8*	*67,8*	*67,5*	*68,2*	*68,2*	*67,7*	*67,2*	*66,5*	*65,6*	*63,8*	*62,6*	*62,8*
Gioia	E6	*69,8*	*71,9*	*71,6*	*72,0*	*71,5*	*71,7*	*72,1*	*72,0*	*72,2*	*71,9*	*71,6*	*72,6*	*72,7*	*73,3*	*72,6*	*71,0*	*71,0*	*71,5*
Bezzi	E2	*71,0*	*72,6*	*73,2*	*72,9*	*72,5*	*71,9*	*71,9*	*72,1*	*72,2*	*71,8*	*72,0*	*72,2*	*72,2*	*72,2*	*71,9*	*70,4*	*70,1*	*70,1*
Corsica	E3	*72,8*	*72,9*	*72,5*	*72,5*	*72,3*	*72,4*	*72,4*	*72,4*	*72,0*	*71,8*	*71,9*	*71,7*	*71,6*	*71,6*	*71,3*	*71,1*	*70,4*	*69,3*
Livigno	F3	*64,4*	*68,5*	*68,6*	*68,4*	*66,6*	*66,2*	*66,3*	*66,7*	*66,6*	*66,8*	*66,4*	*67,2*	*67,3*	*66,8*	*65,9*	*63,8*	*63,4*	*62,7*
Eritrea	E4	*69,8*	*71,7*	*71,8*	*71,4*	*70,8*	*70,8*	*70,9*	*70,8*	*71,0*	*70,6*	*70,1*	*70,5*	*70,5*	*70,7*	*69,8*	*69,1*	*68,4*	*67,8*
Berbera	E1	*69,8*	*73,0*	*73,6*	*72,6*	*72,0*	*71,4*	*71,9*	*72,1*	*72,0*	*72,5*	*73,1*	*73,8*	*73,7*	*73,8*	*72,2*	*69,5*	*68,9*	*68,1*
Testi	D1	*64,3*	*66,5*	*67,5*	*67,0*	*65,8*	*65,2*	*65,8*	*66,8*	*66,1*	*64,9*	*65,9*	*66,4*	*66,4*	*65,1*	*64,5*	*61,5*	*61,5*	*61,3*

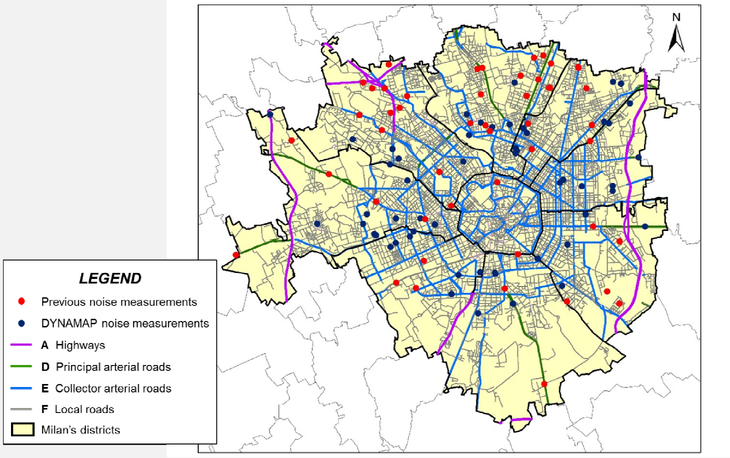
4. RESULTS OF NOISE MONITORING CAMPAIGNS

For the weekdays a total amount of **231 datasets** were obtained: **123** coming from previous noise monitoring activities and **108** coming from the DYNAMAP noise monitoring campaign.
These 231 datasets well describes the noise emissions of **102 roads of Milan**.
Road categories A and D have been almost entirely described, while the E and F road classes, that show an high internal variability, have been the object of a deeper analysis.

ROADS CLASSIFICATION		NUMBER OF ROADS MONITORED	NUMBER OF NOISE DATASET
A - highways		4	13
D - principal arterial roads		9	20
E - collector arterial roads	*E1*	21	61
	E2	10	21
F - local roads	*F0*	18	34
	F1	10	15
	F2	15	32
	F3	15	35
	TOT	*102*	*231*

TOTAL MONITORING DAYS: 609

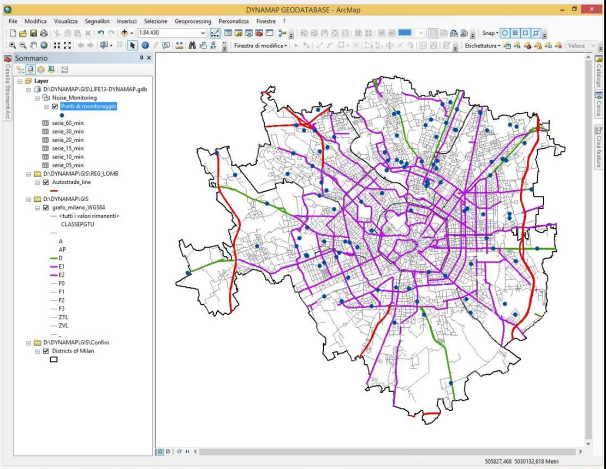
4. RESULTS OF NOISE MONITORING CAMPAIGNS

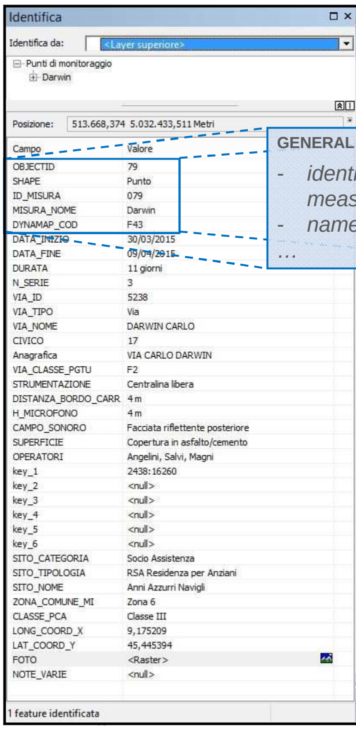


DYNAMAP
Dynamic Acoustic Mapping

5. GEODATABASE

All data presented were collected on a **GIS platform** and inserted into a relational geodatabase (DBMS) purposely created. This tool, not only contains the *acoustic data* and the *georeferenced position* of the measuring points, but it also collects and integrates other information that may be useful for further analysis





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Anagrafica	VIA CARLO DARWIN
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CAMPO_SONORO	Facciata riflettente posteriore
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OPERATORI	Angelini, Salvi, Magni
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SITO_TIPOLOGIA	RSA Residenza per Anziani
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GENERAL INFORMATION

- *identification codes of the measurement*
- *name of the measurement*

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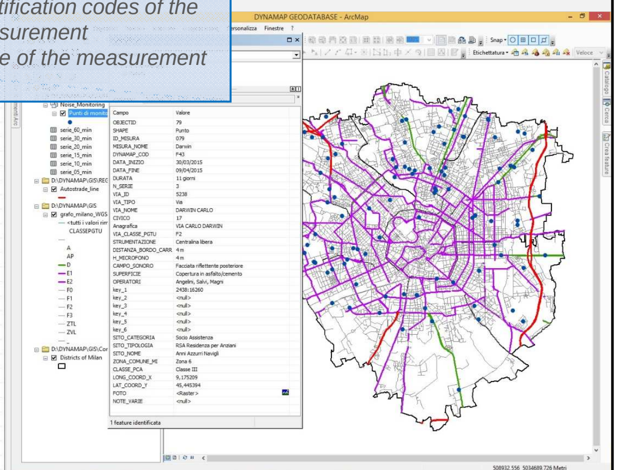

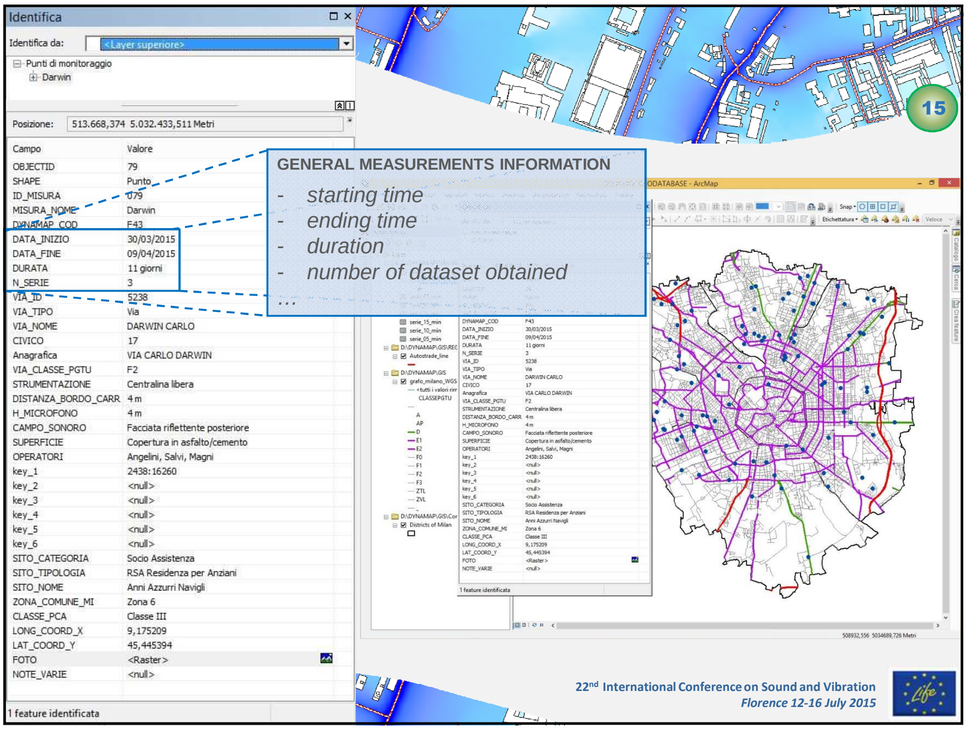
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GENERAL MEASUREMENTS INFORMATION
- starting time
- ending time
- duration
- number of dataset obtained
…
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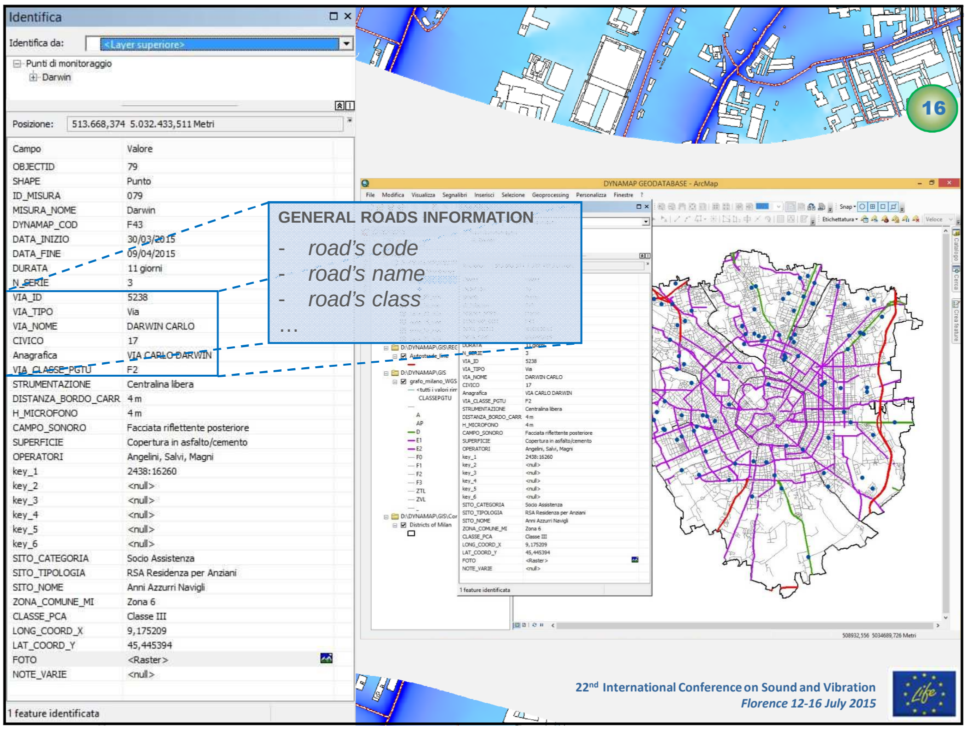
Florence 12-16 July 2015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GENERAL ROADS INFORMATION
- road's code
- road's name
- road's class
…
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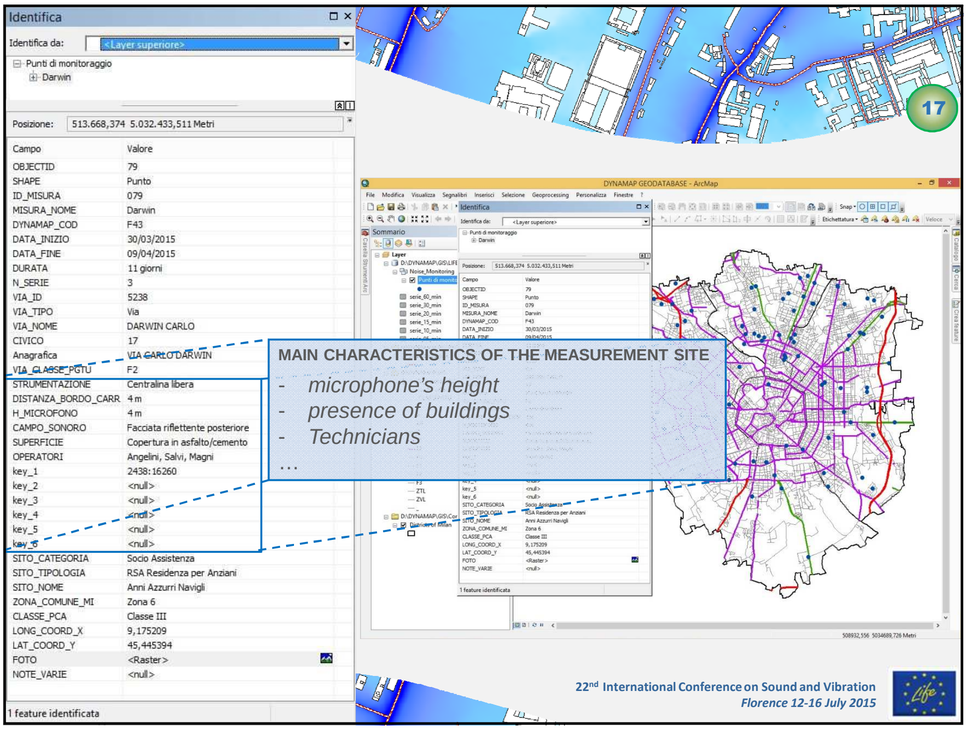
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CLASSE_PCA Classe III
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DYNAMAP GEODATABASE - ArcMap
MAIN CHARACTERISTICS OF THE MEASUREMENT SITE
- microphone's height
- presence of buildings
- Technicians
...
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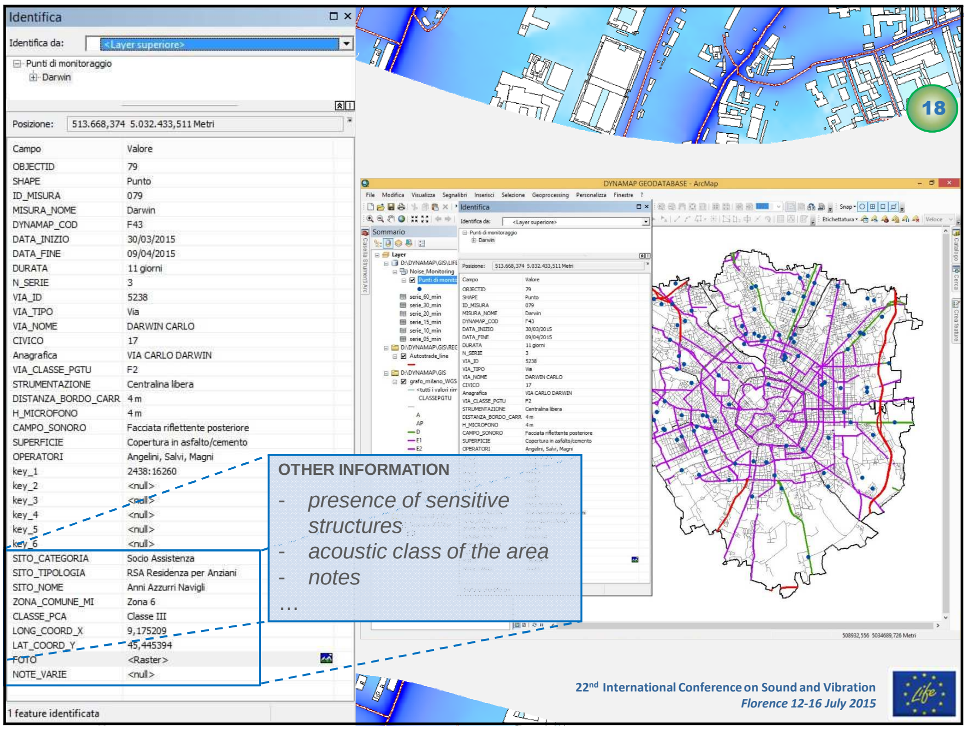
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DYNAMAP GEODATABASE - ArcMap
OTHER INFORMATION
- presence of sensitive structures
- acoustic class of the area
- notes
...
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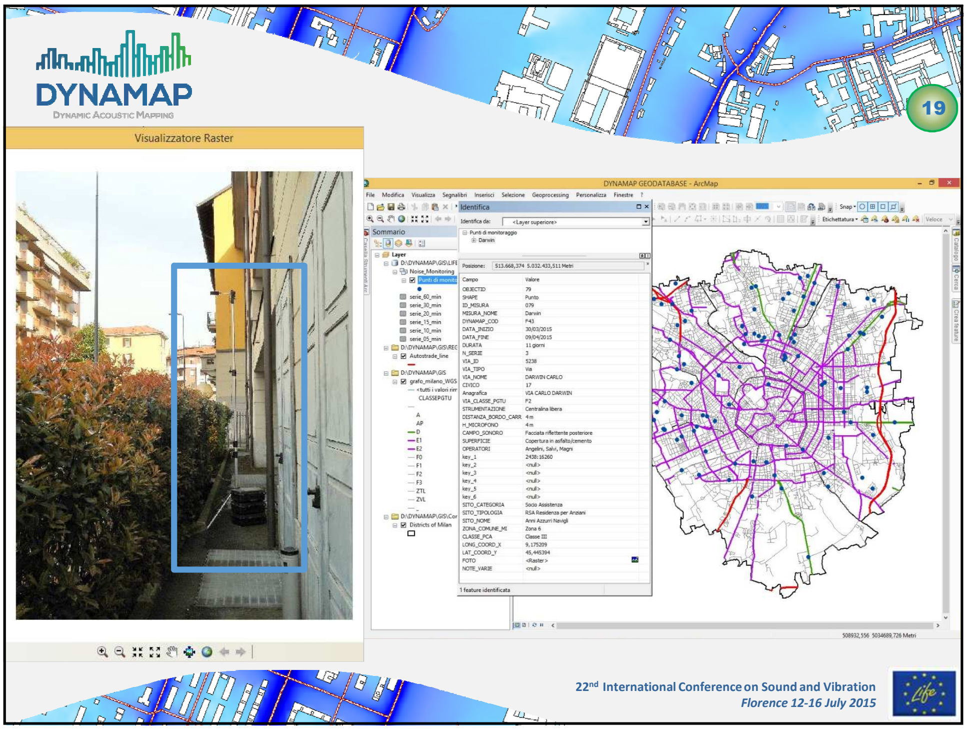
DYNAMAP
Dynamic Acoustic Mapping
19
Visualizzatore Raster
DYNAMAP GEODATABASE - ArcMap
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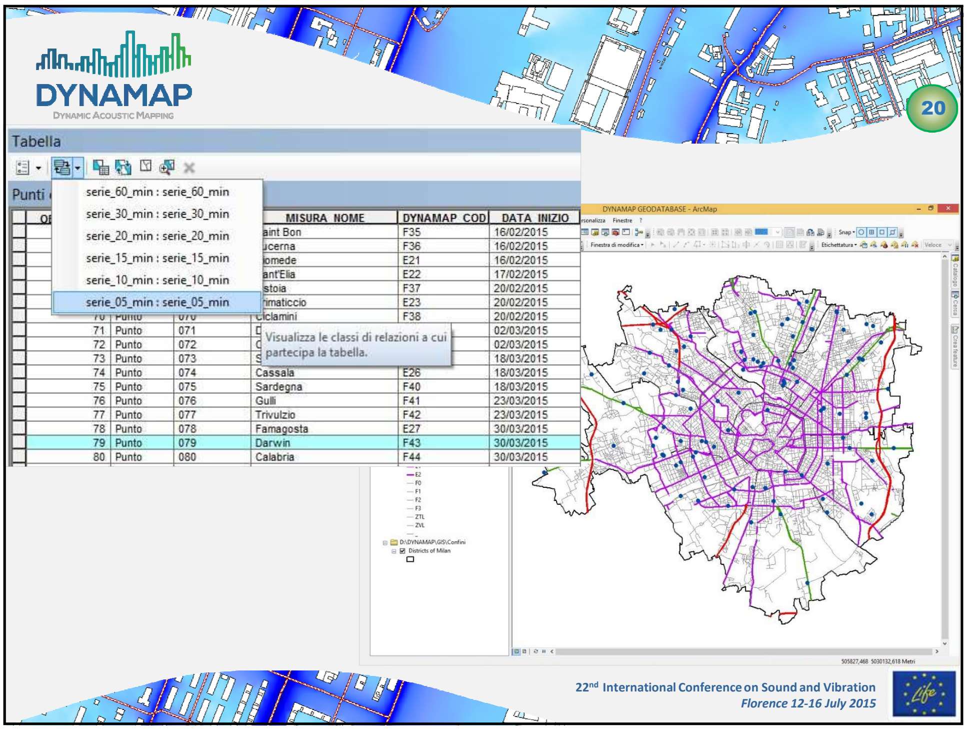
DYNAMAP
Dynamic Acoustic Mapping
20
Tabella
Punti
serie_60_min : serie_60_min
serie_30_min : serie_30_min
serie_20_min : serie_20_min
serie_15_min : serie_15_min
serie_10_min : serie_10_min
serie_05_min : serie_05_min
MISURA_NOME
DYNAMAP_COD
DATA_INIZIO
Visualizza le classi di relazioni a cui partecipa la tabella.
71 Punto 071 02/03/2015
72 Punto 072 02/03/2015
73 Punto 073 18/03/2015
74 Punto 074 Cassala E26 18/03/2015
75 Punto 075 Sardegna F40 18/03/2015
76 Punto 076 Gulli F41 23/03/2015
77 Punto 077 Trivulzio F42 23/03/2015
78 Punto 078 Famagosta E27 30/03/2015
79 Punto 079 Darwin F43 30/03/2015
80 Punto 080 Calabria F44 30/03/2015
DYNAMAP GEODATABASE - ArcMap
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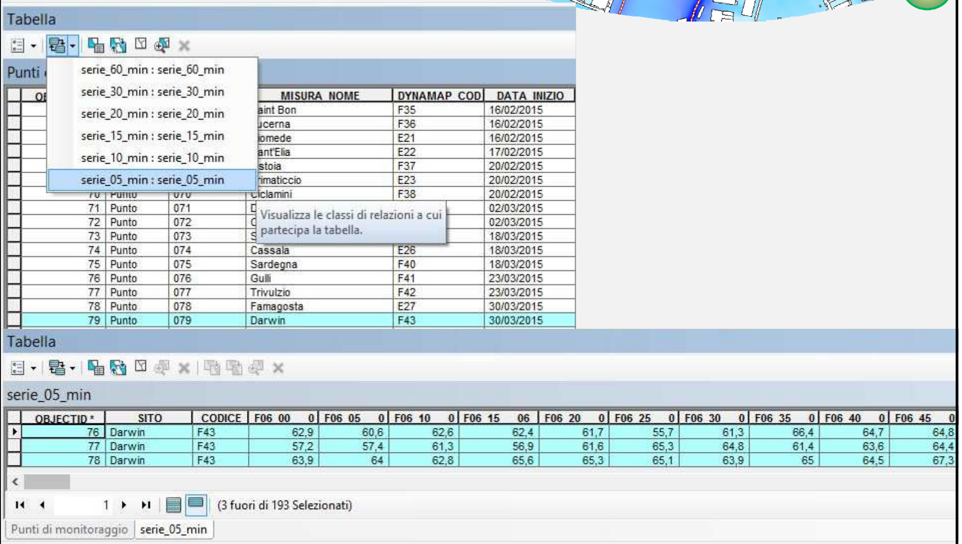

OBJECTID			MISURA_NOME	DYNAMAP_COD	DATA_INIZIO
			aint Bon	F35	16/02/2015
			ucerna	F36	16/02/2015
			iomede	E21	16/02/2015
			ant'Elia	E22	17/02/2015
			stoia	F37	20/02/2015
			rimaticcio	E23	20/02/2015
70	Punto	070	Ciclamini	F38	20/02/2015
71	Punto	071	D		02/03/2015
72	Punto	072	C		02/03/2015
73	Punto	073	S		18/03/2015
74	Punto	074	Cassala	E26	18/03/2015
75	Punto	075	Sardegna	F40	18/03/2015
76	Punto	076	Gulli	F41	23/03/2015
77	Punto	077	Trivulzio	F42	23/03/2015
78	Punto	078	Famagosta	E27	30/03/2015
79	Punto	079	Darwin	F43	30/03/2015

OBJECTID *	SITO	CODICE	F06_00_0	F06_05_0	F06_10_0	F06_15_06	F06_20_0	F06_25_0	F06_30_0	F06_35_0	F06_40_0	F06_45_0
76	Darwin	F43	62,9	60,6	62,6	62,4	61,7	55,7	61,3	66,4	64,7	64,8
77	Darwin	F43	57,2	57,4	61,3	56,9	61,6	65,3	64,8	61,4	63,6	64,4
78	Darwin	F43	63,9	64	62,8	65,6	65,3	65,1	63,9	65	64,5	67,3

5. CONCLUSION

This presentation briefly explains the various activities that have allowed the creation of the **noise data collection**, that will be used in the next stages of the DYNAMAP project.

The **geodatabase** obtained is currently **the largest collection of acoustic trends referred to the road network of the city of Milan** and it's an important basis for any future processing.

Specifically, in the context of the **DYNAMAP project**, the collection of data will be the **basis for the statistical analysis** of the road network in Milan and will represent a **useful tool for the future sizing of the low-cost sensors monitoring network**.

In the future, the amount of data collected could be **increased** and the database could be used for **other processing** and purposes.

The collection of traffic noise trends could be also shared and compared with data obtained in **others urban areas**.

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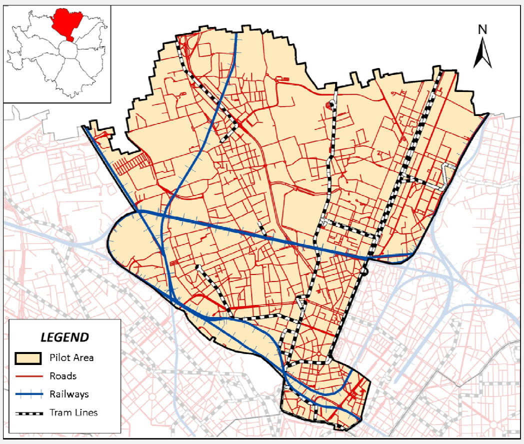
DEVELOPMENT OF OPTIMIZED ALGORITHMS FOR THE CLASSIFICATION OF NETWORKS OF ROAD STRETCHES INTO HOMOGENEOUS CLUSTERS IN URBAN AREAS

Giovanni Zambon, Roberto Benocci, Alessandro Bisceglie

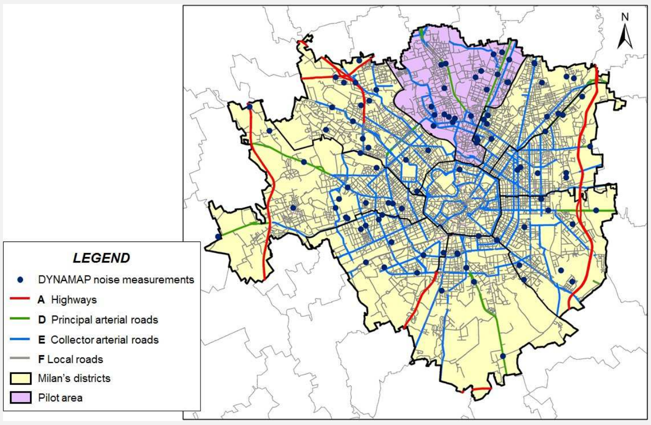
AREA TO BE MAPPED



2233 road stretches

The patterns of traffic flows (and therefore of noise) are very regular and repetitive

The streets can be joined together in a limited number of groups (clusters).
To verify the homogeneity of the groups is necessary to make on site measurements



Measures used to check the homogeneity of the groups: n. 103

Measurement points

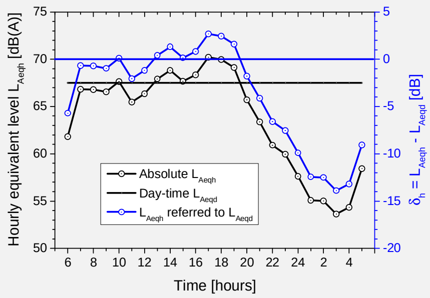
	SITO	Dist. bordo carreggiata (m)	h fonometro (m)	GIORNO	CLASSE	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00
27	Garegnano	0,5	2,5	da giovedì 17/5/2012	F2	55,0	62,3	62,2	60,0	59,1	58,3	60,0	64,5	58,6	58,8	60,0	60,8
28	Suzzani	0,5	2,5	da martedì 2/10/2012	F0	65,6	68,0	68,2	68,5	67,8	68,3	69,9	67,5	67,1	66,9	67,3	67,3
	Suzzani	0,5	2,5		F0	66,3	68,4	68,3	67,4	67,1	66,6	70,5	67,2	67,6	68,0	67,8	68,2
	Suzzani	0,5	2,5		F0	66,0	68,1	68,1	68,7	69,4	68,7	69,0	67,4	68,9	67,4	66,9	68,3
	Suzzani	0,5	2,5		F0	66,5	67,5	69,0	67,6	67,7	67,0	67,2	67,7	67,7	67,4	67,6	67,2
	Suzzani	0,5	2,5		F0	66,8	68,1	69,6	67,7	67,6	68,3	73,0	67,2	67,2	67,4	69,0	67,7
	Suzzani	0,5	2,5		F0	65,9	68,5	68,9	68,3	68,3	69,8	68,0	68,0	68,5	69,1	67,4	71,1
29	Meleri	10	4	da giovedì 25/10/2012	F2	45,7	50,9	56,0	51,1	48,2	49,5	53,3	51,3	48,2	49,8	52,2	50,4
	Meleri	10	4		F2	51,5	59,9	61,3	57,2	51,8	53,4	55,5	50,3	50,1	56,7	57,6	49,8
30	Ugoni	5	4	da lunedì 29/10/2012	E2	59,7	62,2	62,4	61,3	61,0	61,4	61,0	64,4	61,2	61,1	61,5	61,4
	Ugoni	5	4		E2	59,2	61,6	60,4	68,5	61,0	60,6	59,9	60,0	60,3	60,2	61,0	61,9
	Ugoni	5	4		E2	59,6	62,0	63,5	62,0	60,8	60,1	59,8	60,2	60,1	60,1	60,9	61,4
	Ugoni	5	4		E2	58,8	61,6	62,0	60,6	59,4	60,3	60,0	60,3	59,9	60,2	60,6	60,9
31	Iseo	3	4	da mercoledì 21/11/2012	F3	55,1	58,8	62,4	61,6	59,0	57,7	59,4	59,6	59,2	61,9	61,4	59,9
	Iseo	3	4		F3	56,0	57,7	60,3	58,8	58,1	58,2	57,6	61,5	58,6	61,7	62,0	59,7
32	Suzzani	15	5	da mercoledì 21/11/2012	F0	56,9	60,0	60,8	60,7	61,2	60,3	59,9	60,5	60,1	61,0	60,7	59,9
	Suzzani	15	5		F0	57,1	60,0	60,5	60,1	60,7	62,3	62,2	60,6	61,0	60,9	61,1	60,8
33	Novara	4	4	da mercoledì 21/11/2012	E2	67,6	69,7	70,2	69,8	69,1	69,4	69,4	69,9	69,5	70,0	70,8	69,3
	Novara	4	4		E2	68,4	70,7	71,4	70,4	69,8	69,4	70,2	70,9	70,9	69,8	69,3	69,1
	Novara	4	4		E2	69,3	72,5	70,7	71,1	70,1	70,0	69,6	69,6	69,7	69,5	70,9	68,8
	Novara	4	4		E2	67,9	70,0	70,8	70,2	69,3	69,2	70,0	70,6	70,1	69,1	69,9	69,1
34	A8-A9	7	4	da lunedì 11/4/2013	A	75,7	78,3	78,7	78,6	77,8	77,9	78,1	78,1	77,9	78,2	78,0	76,8
	A8-A9	7	4		A	74,7	77,2	77,5	77,0	76,9	76,7	76,6	76,7	76,9	77,3	77,1	77,1
	A8-A9	7	4		A	74,4	77,6	77,5	77,2	76,4	76,3	76,5	76,7	77,3	76,9	76,9	77,1
35	il Moro	2	4	da giovedì 6/2/2013	F0	71,3	72,6	73,1	72,8	72,3	72,3	72,2	71,8	72,0	71,7	70,5	70,5
	il Moro	2	4		F0	57,0	76,5	71,4	57,1	58,0	56,5	58,1	61,2	53,7	54,4	55,7	54,5
	il Moro	2	4		F0	59,5	63,4	58,3	56,7	53,4	55,3	54,3	59,9	53,0	54,3	54,6	56,7
	il Moro	2	4		F0	58,4	63,6	59,3	57,7	56,0	56,9	60,8	65,4	68,3	55,8	59,8	57,5

Examples of hourly noise levels obtained by measurements

Parameter use for roads comparison

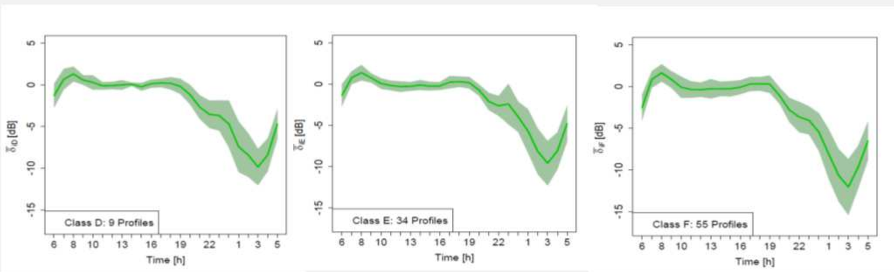
Each *j-th* value of the temporal series was referred to the corresponding daytime L_{Aeqdj} (06-22 h) taken as reference level, that is for each hour the following parameter δ_{ij} was computed:

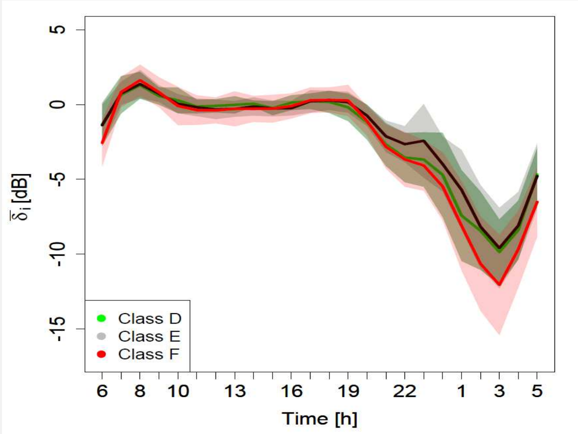
$$\delta_{ij} = L_{Aeqh_{ij}} - L_{Aeqdj}$$ [dB] (i= 1, ………, 103)



Example of the normalization of the 24 h profile of the hourly L_{Aeqh}

Aggregation of the noise levels trend for the different road class D,E,F (defined by italian classification)

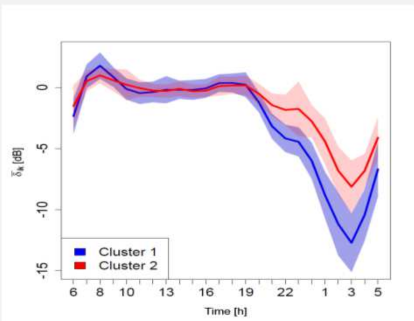


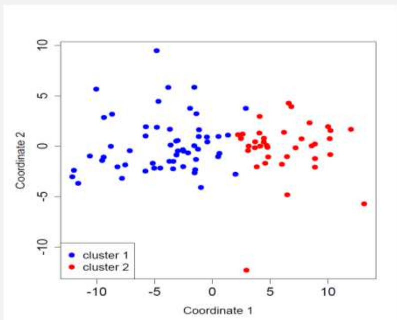


Global view of the three trends: doesn't appear a clear subdivision

Cluster analysis of hourly noise profile

MDS Cluster





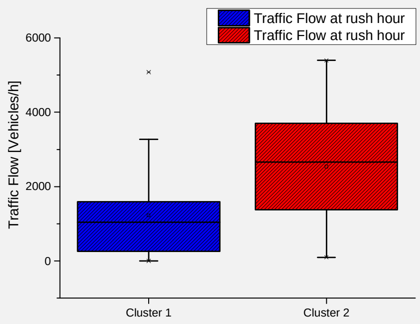
By means cluster analysis we obtain two clusters clearly distinct

The Multi-Dimensional Scaling (MDS) applied to the data provides a visual representation of the pattern of proximities among the data. The distinction among clusters, marked by different colors, is rather good.

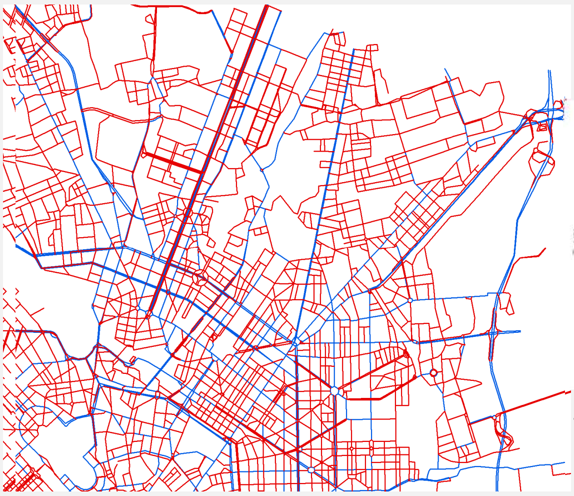
Numerosità	CLASSI			TOT
	D	E	F	
Cluster 1	5	12	43	60
	8%	20%	72%	
Cluster 2	4	18	13	35
	11%	51%	37%	
TOT	9	30	56	95

Distribution of the different road classes D,E,F in the two clusters

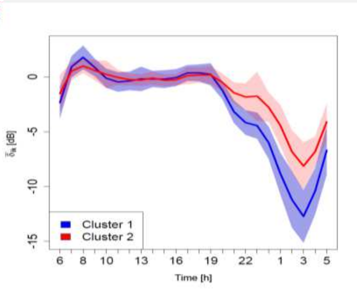
Identification of a non-acoustic parameter for the attribution of a non-monitored road to a cluster.
Rush hour obtained from the traffic model.



The attribution will be made considering the threshold of 1850 V/h



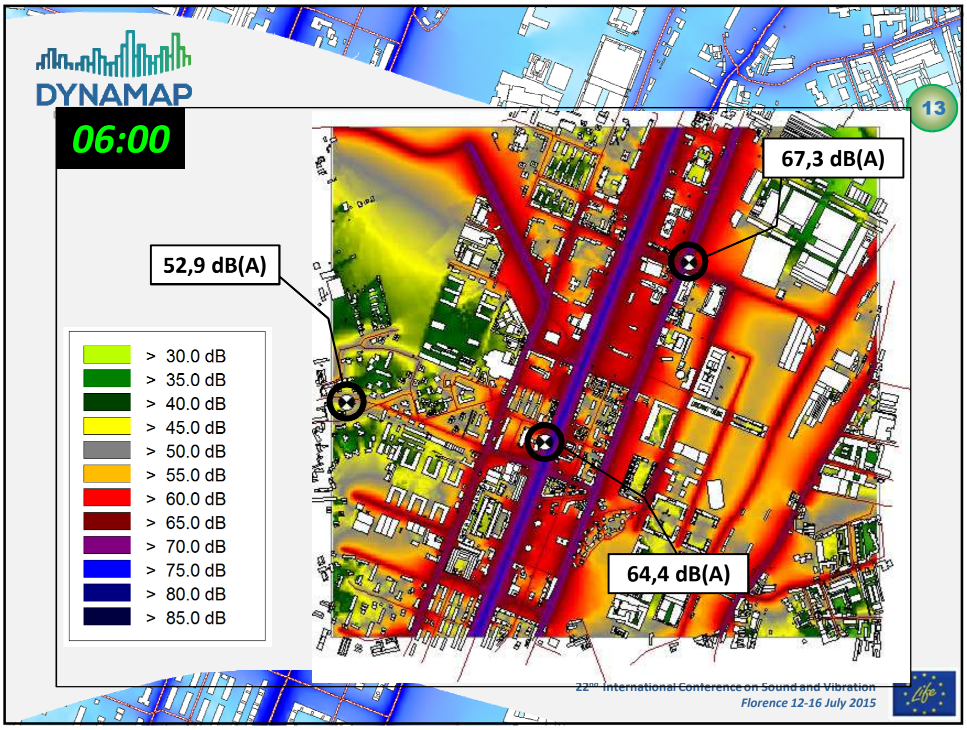
Cluster 1 + Cluster 2



The whole roads network is devided between the two clusters

After the separation of the roads in the two clusters, which will be the pattern of each road, during the mapping?
The one provided by 24 low cost monitoring stations, installed in one of the two clusters.

Starting from two basic maps (one for each cluster of roads), will be possible to get their hourly update. Subsequently, every hour, the two maps will be added together.


DYNAMAP
06:00
13
67,3 dB(A)
52,9 dB(A)
64,4 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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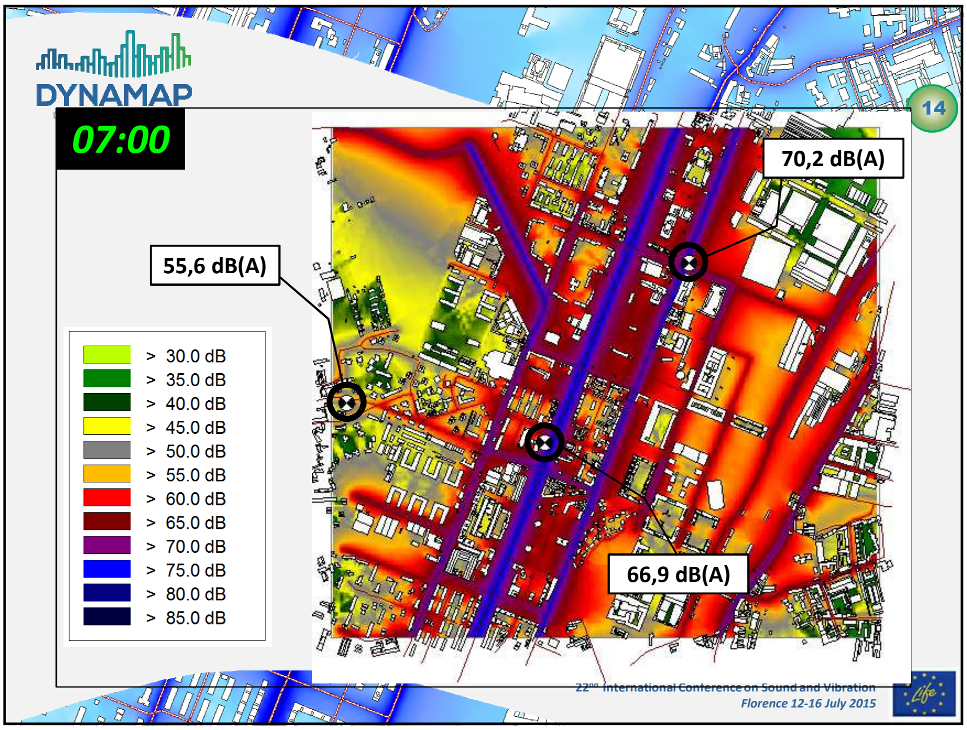
DYNAMAP
07:00
14
70,2 dB(A)
55,6 dB(A)
66,9 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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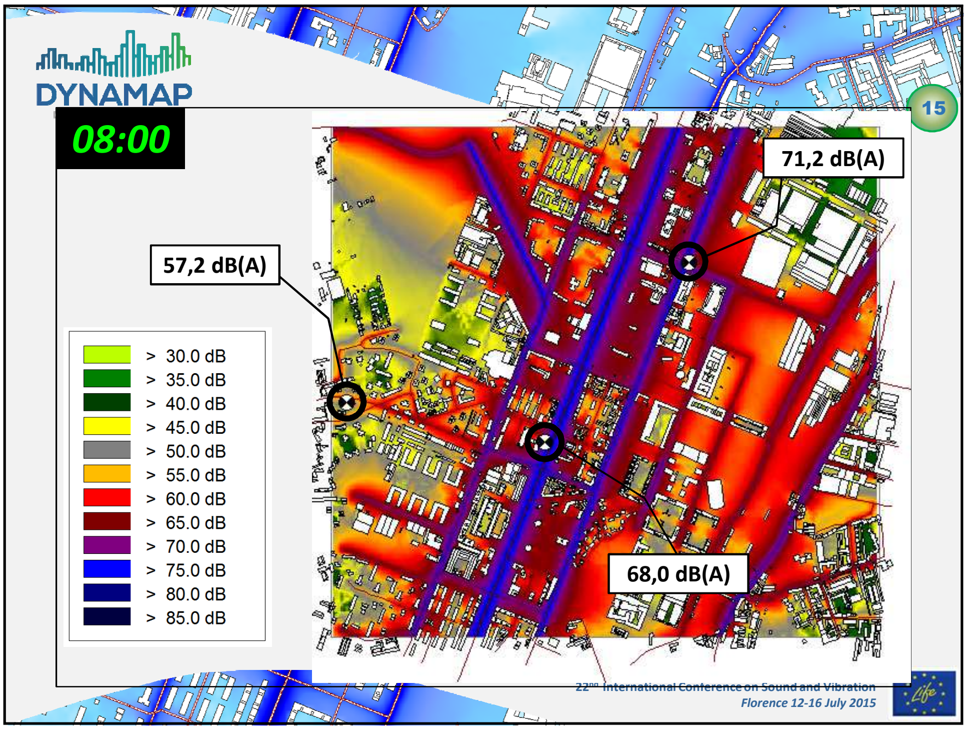
DYNAMAP
08:00
15
71,2 dB(A)
57,2 dB(A)
68,0 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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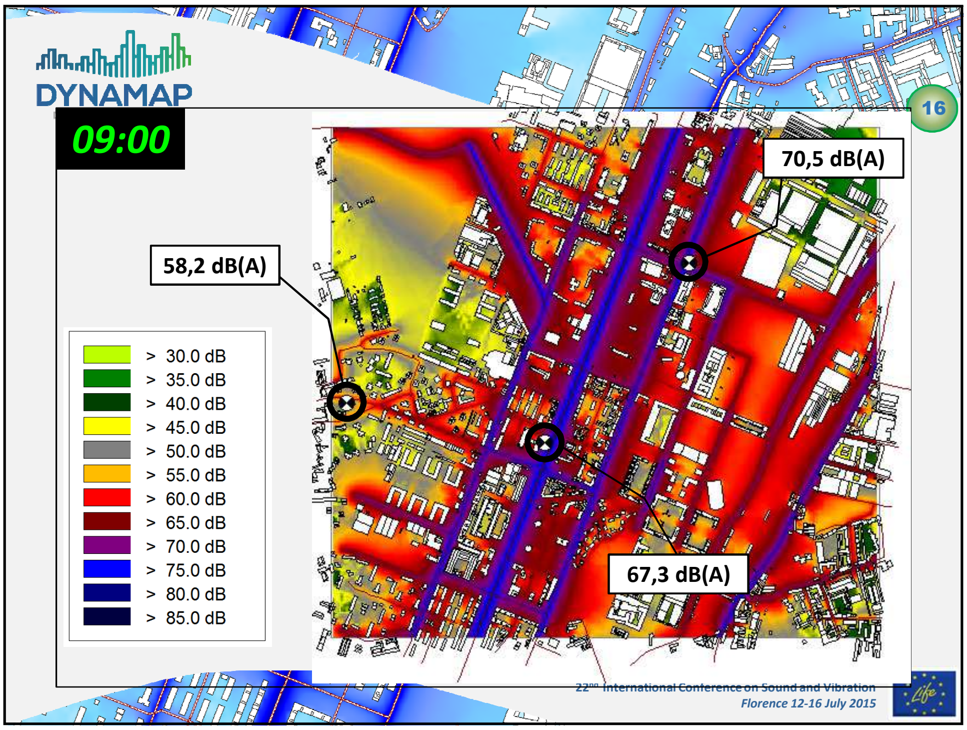
DYNAMAP
09:00
16
70,5 dB(A)
58,2 dB(A)
67,3 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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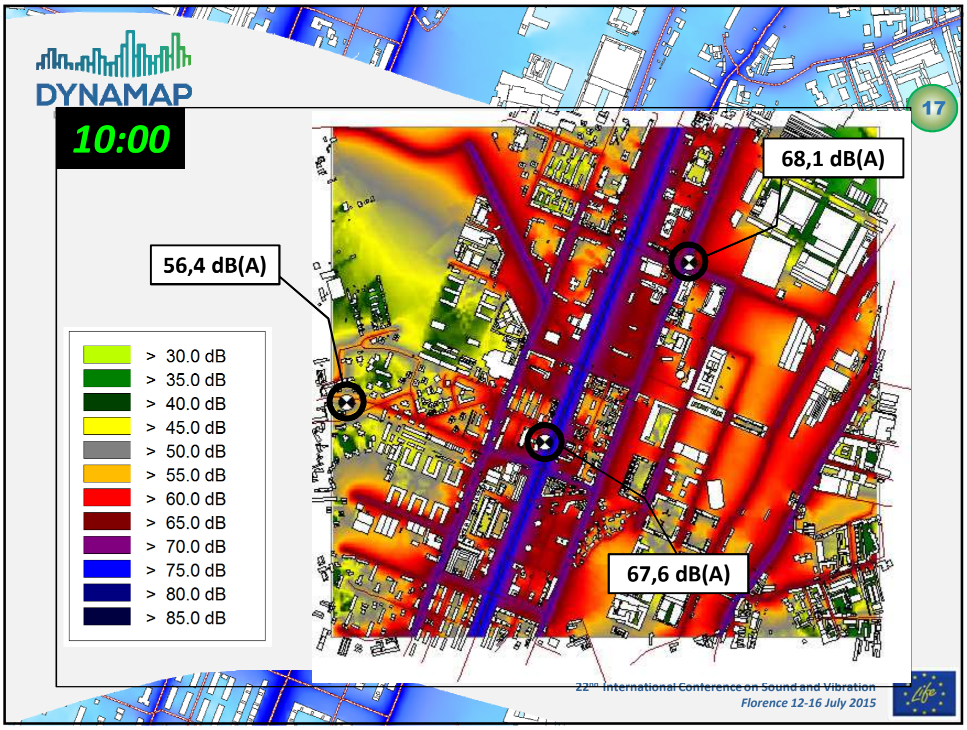
DYNAMAP
17
10:00
68,1 dB(A)
56,4 dB(A)
67,6 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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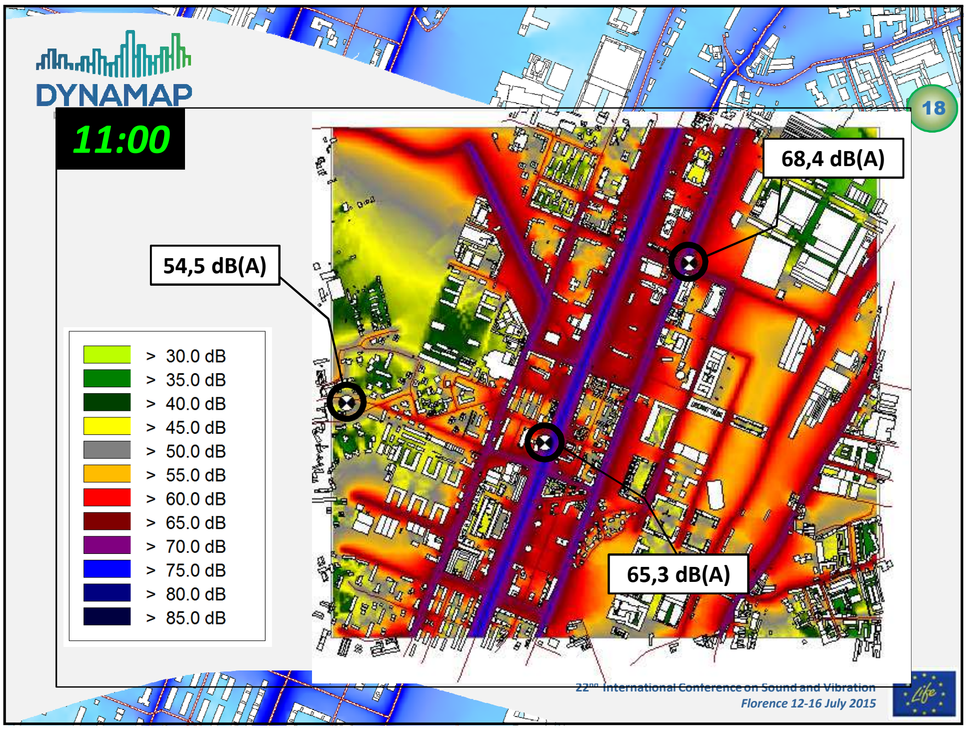
DYNAMAP
18
11:00
68,4 dB(A)
54,5 dB(A)
65,3 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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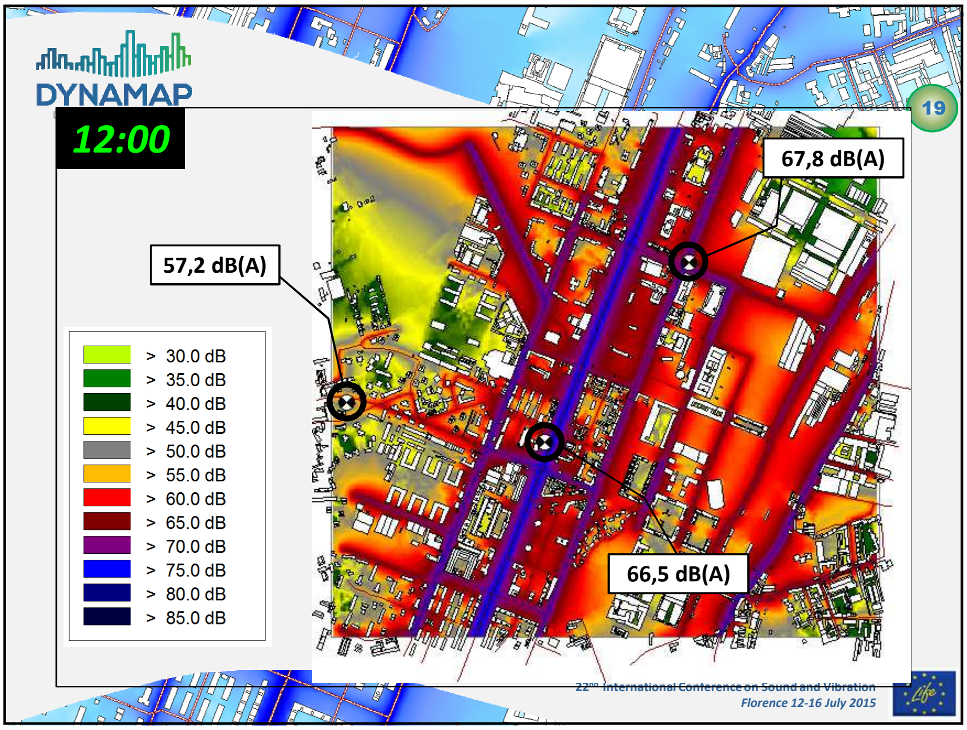
DYNAMAP
19
12:00
67,8 dB(A)
57,2 dB(A)
66,5 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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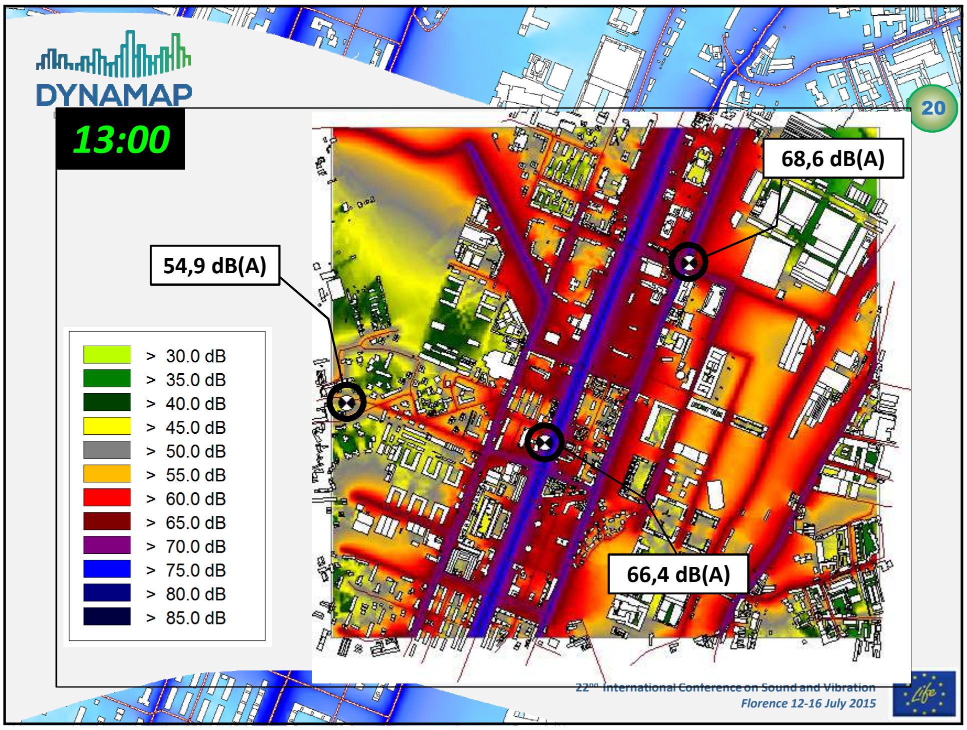
DYNAMAP
20
13:00
68,6 dB(A)
54,9 dB(A)
66,4 dB(A)
> 30.0 dB
> 35.0 dB
> 40.0 dB
> 45.0 dB
> 50.0 dB
> 55.0 dB
> 60.0 dB
> 65.0 dB
> 70.0 dB
> 75.0 dB
> 80.0 dB
> 85.0 dB
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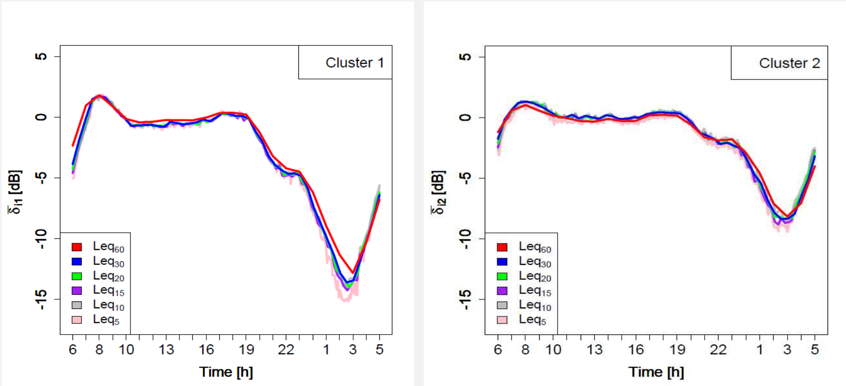
Comparison among mean profiles with different temporal discretization



Good stability of noise profiles for all temporal resolution.

Variation of the road composition within the cluster 1 for different integration time

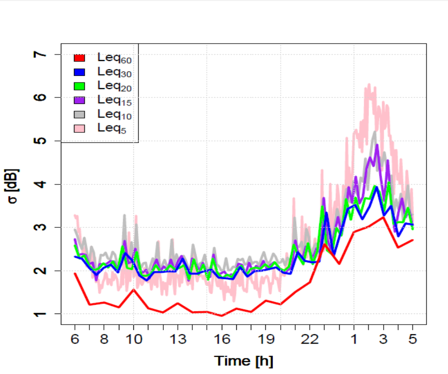
CLUSTER 1

60 min	30 min	20 min	15 min	10 min	5 min
D1	D1	D1	D1	D1	D1
D3	D3	D3	D3	D3	D3
D5	D5	D5	D5	D5	D5
D6	D6	D6	D6	D6	D6
D7	D7	D7	D7	D7	D7
E1	E1	E1	E1	E1	E1
E10	E10	E10	E10	E10	E10
E11	E11	E11	E11	E11	E11
				E12	
E13	E13	E13	E13	E13	E13
E19		E19	E19	E19	E19
E20	E20	E20	E20	E20	E20
				E21	
E22	E22	E22		E22	E22
E23	E23	E23	E23	E23	E23
				E24	
E25	E25	E25	E25	E25	E25
E27				E27	
E5	E5	E5	E5	E5	E5
E7	E7	E7	E7	E7	E7
EZ1	EZ1	EZ1	EZ1	EZ1	EZ1
	EZ2	EZ2	EZ2	EZ2	EZ2
F10	F10	F10	F10	F10	F10
				F1	
F11	F11	F11	F11	F11	F11
F12	F12	F12	F12	F12	F12
F13	F13	F13	F13	F13	F13
F14	F14	F14	F14	F14	F14
F16		F16		F16	F16
F2	F2	F2	F2	F2	F2
F21	F21	F21	F21	F21	F21
F22	F22	F22	F22	F22	F22
				F23	
F24	F24	F24	F24	F24	F24

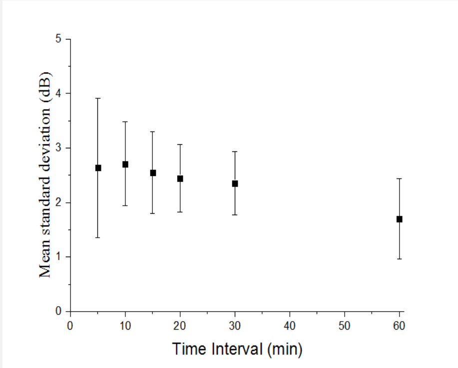
CLUSTER 1

	60 min	30 min	20 min	15 min	10 min	5 min
	F26	F26	F26	F26	F26	F26
	F27	F27	F27	F27	F27	F27
					F28	
	F29	F29	F29	F29	F29	
	F3	F3	F3	F3	F3	F3
	F30	F30	F30	F30	F30	F30
	F32	F32	F32	F32	F32	F32
						F33
	F34	F34	F34	F34	F34	F34
	F36	F36	F36	F36	F36	F36
	F37	F37	F37	F37	F37	F37
	F38	F38	F38	F38	F38	F38
	F39				F39	
	F4					F4
	F40	F40	F40	F40	F40	F40
	F41	F41	F41	F41	F41	F41
	F43	F43	F43	F43	F43	F43
				F44	F44	F44
	F45	F45	F45	F45	F45	F45
	F46	F46	F46	F46	F46	F46
	F48	F48	F48	F48	F48	F48
	F49	F49	F49	F49	F49	F49
	F5					F5
	F50	F50	F50	F50	F50	F50
	F51	F51	F51	F51	F51	F51
	F52	F52	F52	F52	F52	F52
	F54	F54	F54	F54	F54	F54
	F55	F55	F55	F55	F55	F55
	F56	F56	F56	F56	F56	F56
	F57	F57	F57	F57	F57	F57
	F6	F6	F6	F6	F6	F6
	F7	F7	F7	F7	F7	F7
	F8	F8	F8	F8	F8	F8
	F9a				F9a	
	F9b	F9b	F9b	F9b	F9b	F9b
TOT	60	54	56	55	66	59

DYNAMAP
DYNAMIC ACOUSTIC MAPPING



Associated errors to each time interval



Average errors associated to each time interval

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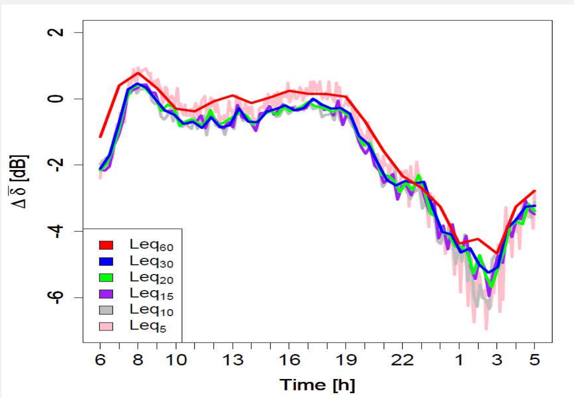

Maximum error associated with a wrong attribution of a road to one of the two clusters

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Dynamic Acoustic Mapping

Hardware specifications update

Luca Nencini

DYNAMAP
Dynamic Acoustic Mapping

BlueWave *Luca Nencini*

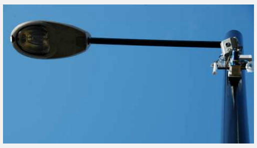
The main goal of the DYNAMAP project is to minimize mapping costs by mean of an **automated** system based on a capillar sensor network distributed over the territory.

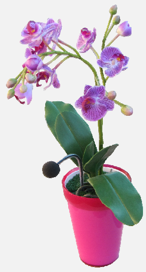
The automation

22nd International Conference on Sound and Vibration
Florence 12-16 July 2015

BlueWave Luca Nencini

Bluewave is developing the **monitoring stations** that will capture acustic data and will send sound levels in real time to a central database by mean of a telecommunication system.

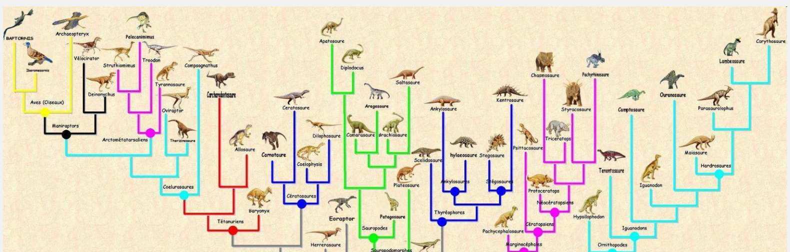




The monitoring station

BlueWave Luca Nencini

The acoustic data must be processed in order to be **classified**. Infact DYNAMAP is aimed at mapping the road noise, thus any non street related acoustic event must be excluded.



The classification

It has been decided that, for each sensor, a classified output like this must be produced every second:

150716113200 58.4 0

T first number is a timestamp, the second is a dB(A) level and the third number is a flag standing for “road” or “non road” event.

This task of anomalous event detection (ANED) could be computationally quite expensive to be carried on a central server.

Bluewave and LaSalle decided to implement the signal processing and the data classification needed to recognize the road/non-road events on each single sensor node.

Thanks to this solution scalability problems can be avoided, distributing the computational load over multiple units

The distributed computing

Luca Nencini

Actually we need to make some preliminary trials in order to measure the computational load of the event recognition algorythm in order to check if a single node is able to support this computational load.

Since LaSalle has to develope the classification algorythm to be implemented on Bluewave sensor nodes, Bluewave and La Salle defined a co-working methodology that allows to develope c ++ code in a standard personal pc and to virtualize the noise sensor node functionality in this pc.

The virtual machine

Luca Nencini

THE HARDWARE

Used hardware is an ARM iMX6 multi core based embedded PC with 2GB ram, internal audio codec at 44100 Khz and 16bit. For data transmission a standard GPRS/3G modem is used.

Minimal version of Linux operating system will be used to run processing scripts

Consumer microphone with floor noise below 35 dB(A) – 6 mm external diameter

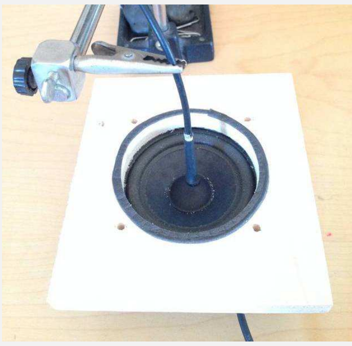
The Microphones

RELIABILITY

Bluewave noise sensors are running since 2011 in the Senseable Pisa project (www.senseable.it)

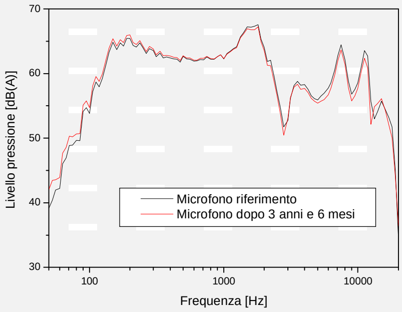
The Senseable Pisa project is carried out by the Dustlab association in order to experiment smart technologies to promote citizen partecipation, crowdsourcing of noise data and big data management.

RELIABILITY



The stability of frequency response of the microphone over long time has been tested.
This test was one unmounting a microphone that has been exposed to atmospheric events for more than three years and comparing it with another never used.

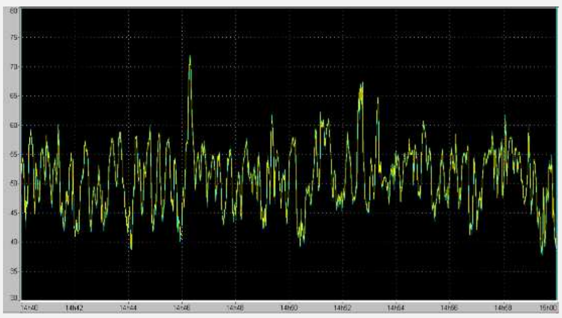
RELIABILITY



Frequency response of a loudspeaker with sine sweep was measured with the aged microphone and compared with the one measured by a new microphone.
Differences of less than 0.5 dB are exibithed over all the spectrum.

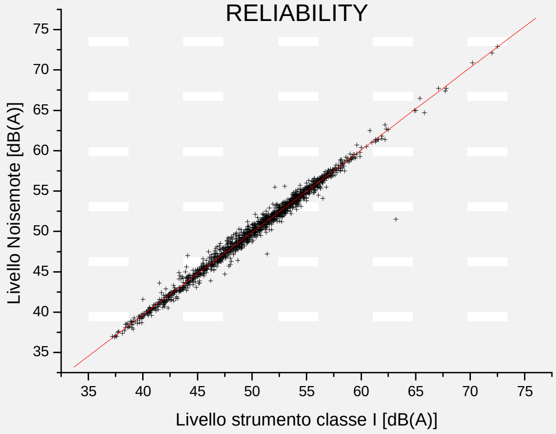
RELIABILITY

Time series of measured sound levels with a low cost microphone compared to class I sound level meter.



Luca Nencini

RELIABILITY



Luca Nencini

CONCLUSIONS AND FUTURE DEVELOPMENTS

We think that the future of noise monitoring will be to reduce more and more:

- size of monitoring devices
- power requirement to make devices eneregetically autonomous in every condition
- management costs of devices and data

This will permit to embed those sensors in every kind of objects as in in the "internet of thing" model, and make a true deep pervasive monitoring.

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DEVELOPMENT OF AN ANOMALOUS NOISE EVENT DETECTION ALGORITHM FOR DYNAMIC ROAD TRAFFIC NOISE MAPPING

Joan Claudi Socoró, Gerard Ribera, Xavier Sevillano, Francesc Alías

DYNAMAP
DYNAMIC ACOUSTIC MAPPING

Outline

1. Introduction
2. Related work
3. System description
4. Experiments and results
5. Conclusions
6. Future work

1-Introduction

- LIFE-DYNAMAP (**Dynamic Acoustic Mapping** - *Development of low cost sensors networks for real time noise mapping*) – (2014-2018). Project goals:
  - Implement Environmental Noise Directive 2002/49/EC
  - Acoustic maps based on low-cost smart grids to ease and perfom its updating.
  - Two pilots: Rome (highway portals) and Milan (district 9)
- Development of an Anomalous Noise Event Detection (ANED) algorithm, that gives support to automatic data record and processing for the acoustic maps, helping in detect noise that only is caused by road traffic.

2-Related work

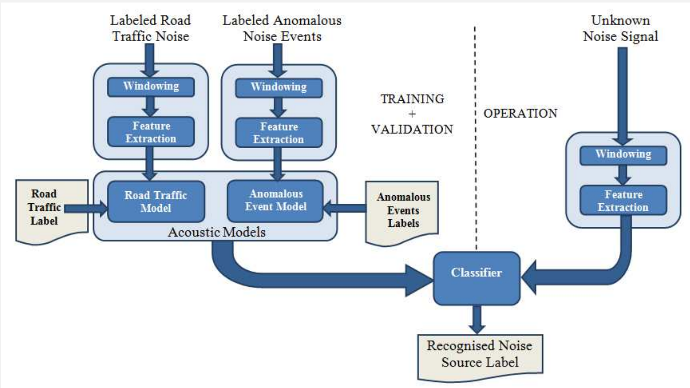
- Detection-and-classification[Tzanetakis, et al. 1999]
  - Based on rapid change against the long-term background noise
  - No need of training on labeled data
  - Problem: stationary background
  - Works: [Vacher et al., 2003] [Vacher et al., 2005][Tartakovsky et al. 2014][Dessein et al. 2013][Cont et al. 2011][Bietti 2014]
- Detection-by-classification [Temko, 2007]
  - Classification of signal frames and event detection by category
  - Works: [Dennis 2014] [Tzanetakis, 1999][Zhou et al. 2007][Zhuang et al. 2010][Cotton et al. 2011][Schroder et al. 2013]

3-System description

- Detection-by-classification(RTN contains rapid changes)
- Two-categories: RTN vs. ANE
- Types of ANE:
  - Highly local (e.g. railways, airports, etc.)
    - ANE model based on learning from recorded samples is highly viable
  - Unpredictable and highly diverse (e.g. sirens, horns, thundering, etc.)
    - ANE model becomes a difficult task
  - Little likely to occur (e.g. a bird or a cricket that approaches the sensor)
    - ANE model is hardly feasible
- Proposal:
  - Location-independent ANED algorithm based on a semi-supervised approach that avoids creating acoustic models for the minority ANE class.

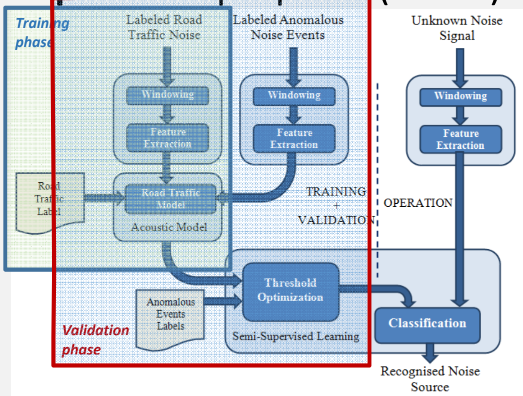
3-System description

- Supervised **baseline** technique



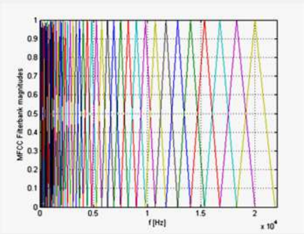
3-System description

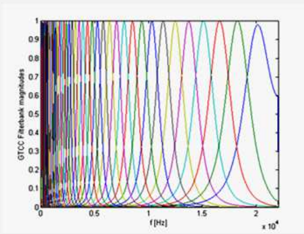
- **Semi-supervised** proposal (ANED)



3-System description - Audio features

- MFCC [Benetos et al, 2006][Shen et al. 2009][Beritelli et al, 2008][Peltonen et al, 2002]
- GTCC [Valero et al 2012a][Valero et al 2012b][Valero et al 2013]
    - More accurate biologically-inspired model of human auditory system.
    - 48 logarithmically spaced subbands (also in MFCC)
    - Gamma impulse response → 4^{th} order discrete filter
- Audio frames of 30ms and P vector of 13 coefficients





3-System description - Classifiers

- ML methods that provide a metric (distance/probability):
  - K-Nearest Neighbour (KNN):
    - Based on labeled database
    - Euclidian distance between P and the K closer examples in database
  - Fischer Linear Discriminant (FLD):
    - Statistical model
    - Log-probability that the model is the source of the observed vector P
- Strategies:
  - **Supervised**: RTN and ANE models, classification based on the most likely model (that minimize/maximize the metric).
  - **Semi-supervised**: only RTN model, classification based on if the metric surpasses a given threshold (RTN vs ANE).

3-System description - Threshold optimization

- Semi-supervised technique (ANED)
- Threshold is computed so as to minimize type I (false positives) and type II (false negatives) errors.
- Idea taken from the field of speaker verification [Furui, 1981]
- Optimal threshold is obtained by the crossing point between the *pdf* of the metric when classification result is correct and the *pdf* of the metric when classification result is erroneous.

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4-Experiments and results

- Database:
  - RTN: 250 sec. of recordings from Barcelona ring, using Bruel&Kjaer 2250 Sonometer (48 KHz, 4.2 Hz - 22.4 kHz freq. range, mic Type 4189).
  - ANE: 300 seconds of 15 noise types gathered from free online repositories (i.e. horns, ambulance sirens, car collisions, church bells, birds, crickets, rain, thunders, etc.)
- Training + Validation + Test with synthetic mixes:
  - RTN-to-ANE: -6 and -12 dB.
  - 4-fold cross-validation:
    - Training models: 75% (reference), 37.5% (ANED)
    - Threshold optimization (*Validation*): 37.5% (ANED)
    - Test: 25% (both reference and ANED)

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4-Experiments and results

- A total of 16 simulations have been carried out

		RTN-to-ANE = -12 dB				RTN-to-ANE = -6 dB			
		FLD		KNN		FLD		KNN	
		GTCC	MFCC	GTCC	MFCC	GTCC	MFCC	GTCC	MFCC
Referència	$F1_{ANE}$	0,7877	0,7990	0,8305	**0,8266**	0.6983	**0.8233**	0.7738	**0.8478**
	R (%)	85.25	85.62	87.26	**86.42**	77.43	84.58	**83.77**	**87.12**
ANED	$F1_{ANE}$	**0,8976**	**0,8397**	**0,8440**	0,7710	**0.8252**	0.7906	**0.7810**	0.6718
	R (%)	**91.46**	**87.22**	**87.70**	83.35	**84.56**	**84.79**	79.97	76.82

- Performance comparison: recognition rate (R in %) and F1 measure

- ANED outperforms the baseline detector in 5 out of 8 cases
- Scenarios with lower RTN-to-ANE (-12 dB) are those where ANED proposal has better performance.
- Best result: FLD classifier, GTCC, and RTN-to-ANE of -12 dB

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5- Conclusions

- New strategy for conducting anomalous noise event detection in road traffic noise monitoring systems
- **Distance-based (or probabilistic) classifier** is needed to perform the threshold optimization, obtaining a more location-independent approach.
- Validation of the strategy in a controlled scenario based on **synthetic mixes** of RTN and ANE
- **Semi-supervised strategy**: only RTN model and threshold optimization with less samples of ANE than baseline.
- Improved behaviour (91%) than the supervised counterpart
- Greater robustness in low RTN-to-ANE ratios (-12 dB)

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6-Future work

- Exploitation of the temporal dynamics of the detection to increase its robustness
- Evaluation of different system setups (e.g. different features sets and classifiers – GMM's)
- Exploration of early and late fusion schemes
- Adaptation of the proposed approach to specific acoustic environments

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Thanks for your attention

Any question?

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BASIC SECONDARY ASPECTS OF THE LIFE DYNAMAP PROJECT

Patrizia Bellucci, **Laura Peruzzi**

ANAS S.p.A. - Research Centre, Rome (Italy)

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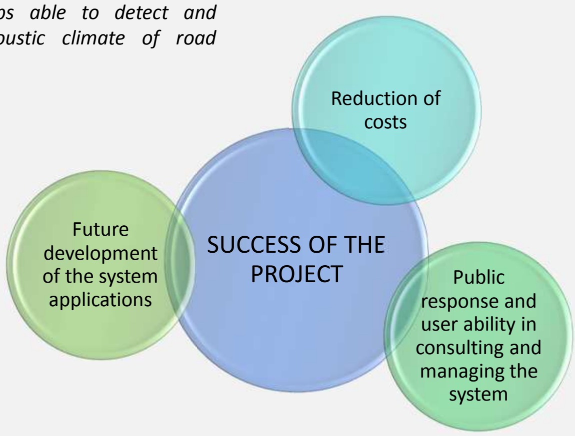
The main aim and outcome of the Dynamap project is the provision of dynamic noise maps able to detect and represent in real time the acoustic climate of road infrastructures.

SECONDAY OBJECTIVES OF THE DYNAMAP PROJECT



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EXPECTED COST AND BENEFITS OF THE DYNAMAP SYSTEM

COSTS AND BENEFITS CAN'T BE CONSIDERED SECONDARY ASPECTS FOR THE SUCCESS OF THE PROJECT, BUT BASIC SPECIFICATIONS TO BE FULFILLED TO REACH THE FINAL GOAL.

COMPREHENSIVE COSTS AND BENEFITS ANALYSIS

- Assess the feasibility and economic sustainability of the system on a large scale.

REAL TIME INFORMATION ON THE ACOUSTIC CLIMATE

- Noise mapping costs can be reduced and that benefits can be improved by providing up-dated real time information on the acoustic climate of road infrastructures at any place and time.

SUCCESS OF THE PROJECT

- Depends on the economic burden required to local and central authorities for implementing the system compared to costs and benefits associated to traditional noise mapping procedures

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Cost And Benefits Analysis

Two pilot areas

- A90 motorway - Rome — Whole ANAS network
- Distric n°9 - Milan — Agglomeration of Milan

- demonstrate the feasibility and economic sustainability of the system;
- develop a standardized method for assessing costs and benefits based on the most recent results available in literature.

Refer to a static scenario prepared following the traditional noise mapping procedures and accomplished in three steps

COSTS EVALUATION + BENEFITS EVALUATION = COSTS/BENFITS ANALYSIS

1. An estimate of the expected costs of the system will be given and compared to costs related to traditional noise mapping methods

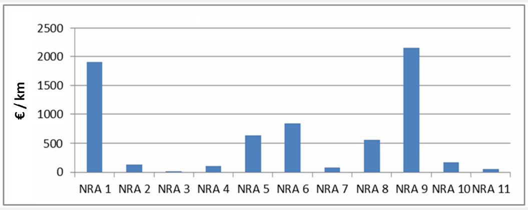
2. Benefits will be identified and quantified taking into account the effects associated to the efficiency of the two options in terms of rapidity of response, evaluation accuracy and impact on the population

3. Cost-benefit analysis of the Dynamap system will be accomplished to assess the feasibility and economic sustainability of the Dynamap system on a large scale

THE COSTS OF TRADITIONAL NOISE MAPPING ACTIVITIES

CEDR (the Conference of European Directors of Roads) Working Group Road Noise in 2013

Questionnaire referred to the first cycle of strategic noise mapping (END)



Noise mapping costs provided by eleven National Roads Administrations (NRA) for the first cycle of strategic noise mapping

RESULTS: **costs depend on the possibility of outsourcing or arranging in house activities**

Noise mapping activities → **average cost of €160**.

Outsourced costs → **average value of 604 € per kilometer**

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Expected costs of the Dynamap system

First estimate costs of dynamic noise mapping

Simple calculation refer to the expense that should be paid to prepare the pilot area of Rome			
Monitoring stations	Installation	Maintenance for 20 years	Preparation of the first set of basic noise maps

Final cost: less than a half of the average cost reported by CEDR

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PUBLIC RESPONSE AND USERS ABILITY IN CONSULTING AND MANAGING THE SYSTEM

DIRECTIVE 2002/49/EC

- Strategic noise maps and action plans are made available and disseminated to the public

DIRECTIVE 90/313/EEC3

- Give free access to environmental information

CEDR Project Group Road Noise

- Report on action plans
- 17 National Roads Administrations (NRA) - Consultation period of at least 8 weeks
- Advertisements in newspapers (80%), websites (100%) and public hearing meetings (30%).
- No useful feedback

LIFE HARMONICA

- Innovative tools to better inform the public
- Creation of a simple, dimensionless noise index
- Database on noise abatement actions published on an interactive platform to share useful information and experiences.

The communication approach foreseen in the DYNAMAP project

Software to dynamically update noise maps in real time → GIS file → Software application for real-time web presentation of the results to the public

This software application will be designed to plot colored geo-referred noise maps to be published on the system's web site in a user-friendly format and also other environmental data, such as air quality, weather and traffic conditions, when available.

Different users categories:

- low privilege; general public, able to plot only noise maps
- high privilege; authorized stakeholders, able to see the time history of noise levels, some statistics and additional parameters linked to the sensors installed in each monitoring station.

ITERATIVE PROCESS TWO TEST SESSIONS

FIRST TEST TYPE

- to system's operators
- aims at assessing users ability in managing the system.
- direct observation of system managing skills and the compilation of a technical evaluation form.

SECOND TEST TYPE

- stakeholders and the general public
- remote access to the system through the project website and compilation of a short questionnaire

Questionnaire:
questions on project tools capability of raising people awareness on noise through freely accessible information and communication from the website

MONITORING OF ACTION PLANS

- check the effectiveness of the information delivered to the public
- preparation for the agglomerations of Milan and Rome
- verify their actual participation in selecting and adopting proper noise mitigation measures.

FUTURE VISION ON SYSTEM APPLICATIONS

Two actions addressing how to upgrade the system by adding environmental sensors to the DYNAMAP monitoring stations and how to obtain information for traffic management and control from the sensors.

1° TASK

HARDWARE

how the DYNAMAP system should physically communicate with external devices

2° TASK

ANED ALGORITHM

inclusion of additional sensors to correlate noise measures and other sensed parameters

more information to determine whether a set of high noise values are due to actual anomalous events

3° TASK

SOFTWARE

creation and publication of dynamic maps referred to additional environmental parameters, including the management of the access to the new environmental data sets

Main difficulties associated to the upgrade with additional environmental sensors → **SENSOR TECHNOLOGY**

which should be the way to interface the DYNAMAP system with hypothetical added sensors?

To avoid future restrictions and reduce the probability of incompatibility, sensors front-end will be considered as part of the sensors themselves.

System will operate as an open structure

Sensors output will be treated just as simple electrical signals, making the system easily adaptable to a wide range of devices.

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Traffic management and control based on information retrieved from sensors

Source of valuable information about the status of traffic

MITIGATION ACTIONS

Long Term

- most critical areas in terms of noise and atmospheric pollution can be identified and action plans to mitigate the noise impact can be addressed

→ *the construction of acoustic barriers and low-noise pavements, planting of trees to compensate for air pollutants, traffic calming policies and ITS systems for controlling and managing vehicles speed and traffic flow in real time*

Short Term

- detection of high traffic noise levels in certain areas at a specific moment

→ *warning system based on the interconnection between the DYNAMAP system and electronic roadside informative boards*

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CONCLUSIONS

ECONOMIC SUSTAINABILITY

- Costs/benefits analysis
- Significant reduction in noise mapping costs and perceptible benefits

MANAGE THE SYSTEM AND INFORM THE PUBLIC

- Iterative process and a series of tests
- To Check users’ ability in accessing information and managing the system

FUTURE APPLICATIONS

- Integrated and comprehensive overview of road infrastructure impact
- Connection to intelligent transportation systems (ITS)

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Thanks for your kind attention

l.peruzzi@stradeanas.it

What cities could desire from dynamaps.

Mr H.Wolfert EUROCITIES

- Introduction
- EUROCITIES-WG Noise
- FONOMOC
- Link between FONOMOC- DYNAMAP

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FONOMOC

Aims to:

- Exchange of knowledge and experience on noise monitoring systems
- To carry out peer reviews (city to city)
- To identify new developments and innovations
- To identify and to collaborate in EU funded projects (H2020, LIFE, INTERREG and URBACT)
- Improve communication on noise levels found
- To promote noise monitoring and to elaborate and use Big Data

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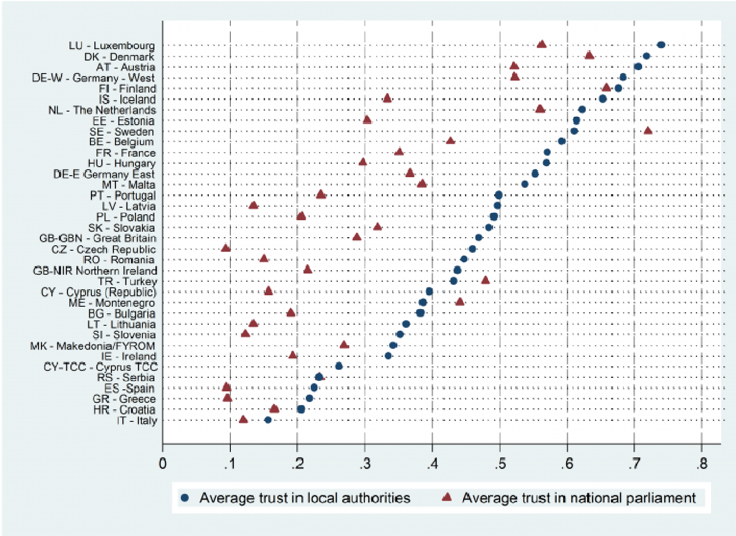
- Present the noise levels to the public
- Present noise levels at any time and time based
- People can follow the trends
- Present the noise levels to the politicians
- Link the noise levels found and complaints
- Validate the noise propagation model
- Gives evidence that low cost sensor are reliable
- Takes away mistrust gives transparency



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- END -

Thank you for your attention!!

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FROM THE POINT OF VIEW OF REGIONE LOMBARDIA

Pietro Lucia - Regione Lombardia
Steering Committee Dynamap

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THE ROLE OF REGIONS

- Deriving from statements of Decreto Legislativo 194/2005 (Law by decree), implementation of END (Directive 2002/49/CE) in Italy
- Region defines agglomerations for END noise mapping
- Region defines authority responsible for END noise mapping of agglomeration
- Region check the compliance of noise maps to END and D.lgs. 194/2005 (annexes)

REGIONE LOMBARDIA

- **Four agglomerations, one of them is Milan agglomeration**
- **Boundaries of agglomeration coincide with boundaries of municipal district**
- **Milan municipal government is responsible for END noise mapping of Milan agglomeration**

MAIN CONCERN

- **Compliance of noise mapping to END and D.Lgs. 194/2005**

DESIDERATA 1

- Aim at coverage of agglomeration area
- Support to decisions and policies

DESIDERATA 2

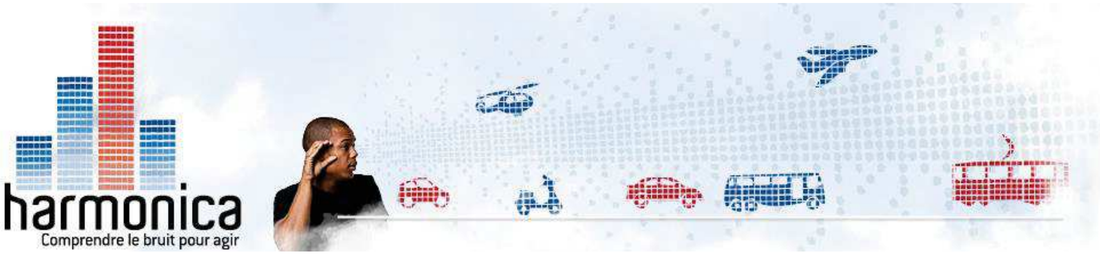
Extension of coverage vs frequency of updating: a reasonable and sustainable equilibrium

THANK YOU

HARMONICA PROJECT

News tools to inform the public about environmental noise in cities and to assist decision-making

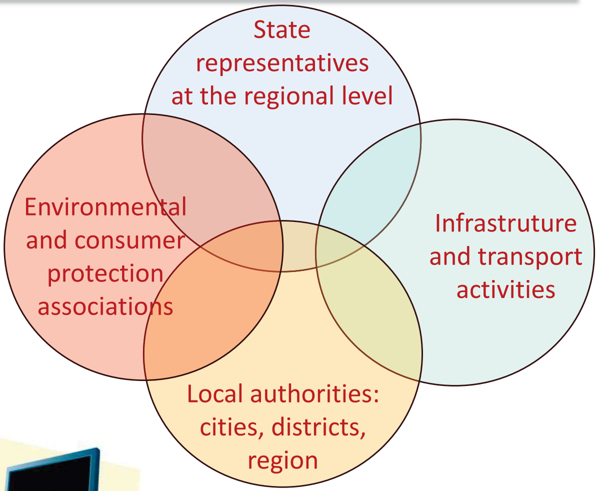
www.noiseineu.eu

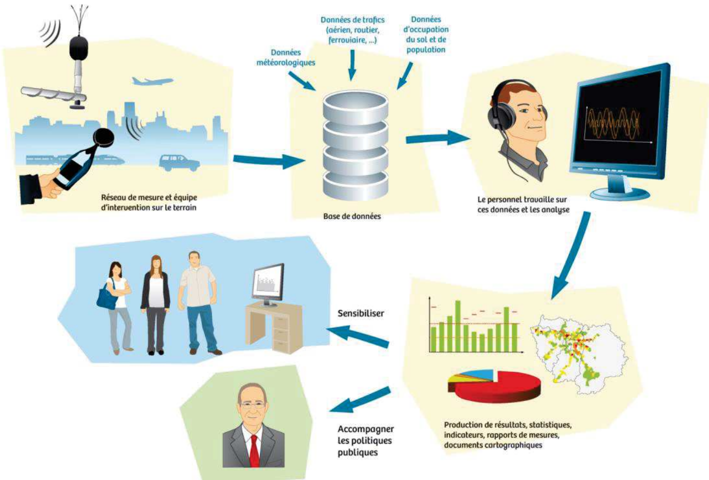


OUTLINES

- Brief overview of the noise observatory Bruitparif and the Île-de-France region
- Results of the HARMONICA project
- Possible links between DYNAMAP and HARMONICA

Bruitparif, what is it?





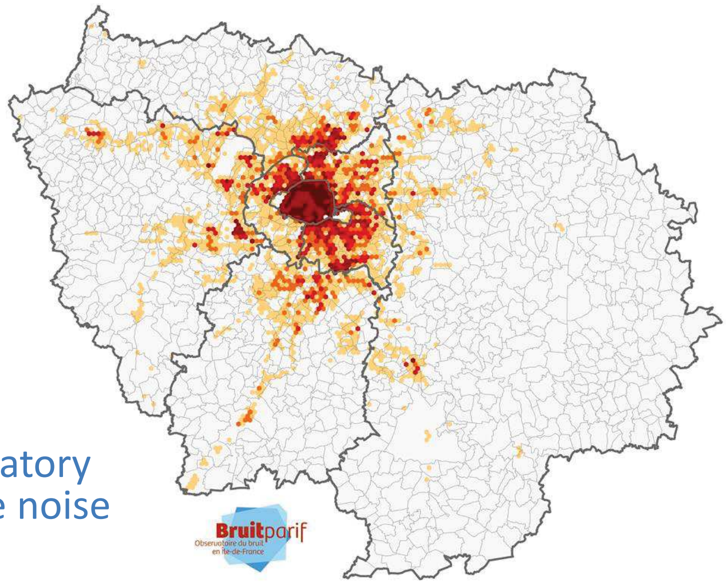
The Paris region « Ile-de-France »

- 12 000 km^2
- 12 million inhabitants
- 40 000 km of roads
- 1 800 km of railways
- 3 main airports
- 71% of inhabitants said they are annoyed by noise at home

→Need for a regional noise observatory to get reliable information on the noise levels in the Ile-de-France region

→Bruitparif was created in 2004

- END application
  - 20% of the population are exposed to noise levels that exceed the French limit values



Map: Population density that exceeds noise limit values

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The LIFE HARMONICA Project

Bruitparif
Observatoire du bruit
îledeFrance

HARMONICA = HARMOnised Noise Information for Citizens and Authorities

- **Co-funded over 3 years and 3 months (01/10/2011-31/12/2014) by EC**
- **Two French non-profit associations specialised in the observation of environmental noise:**
  - Coordinator : Bruitparif for the Ile-de-France region (12 000 km^2, 12 millions inhabitants, 45 long-term measurements stations, www.bruitparif.fr)
  - Associated partner : Acoucité for the Greater Lyons agglomeration (516 km^2, 1,3 million inhabitants, 18 long-term stations, www.acoucite.org)
- **Several objectives:**
  - Make information on noise more accessible and closer to people's perceptions
  - Assess noise abatement actions in a harmonised way and promote effective actions
  - Facilitate the transfer of this approach to European cities
  - Contribute to the development of a common and shared culture about noise

DYNAMAP
Dynamic Acoustic Mapping

3 new tools

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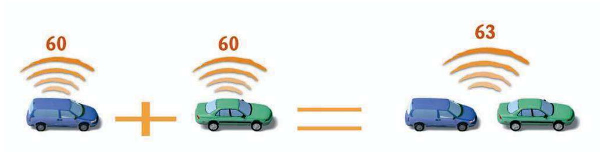
- **The Harmonica index**
- **A collaborative database of noise abatment actions**
- **An on-line platform www.noiseineu.eu to display Harmonica index results coming from different cities in Europe and to share best practices**

The Harmonica index: Why a new noise index ?

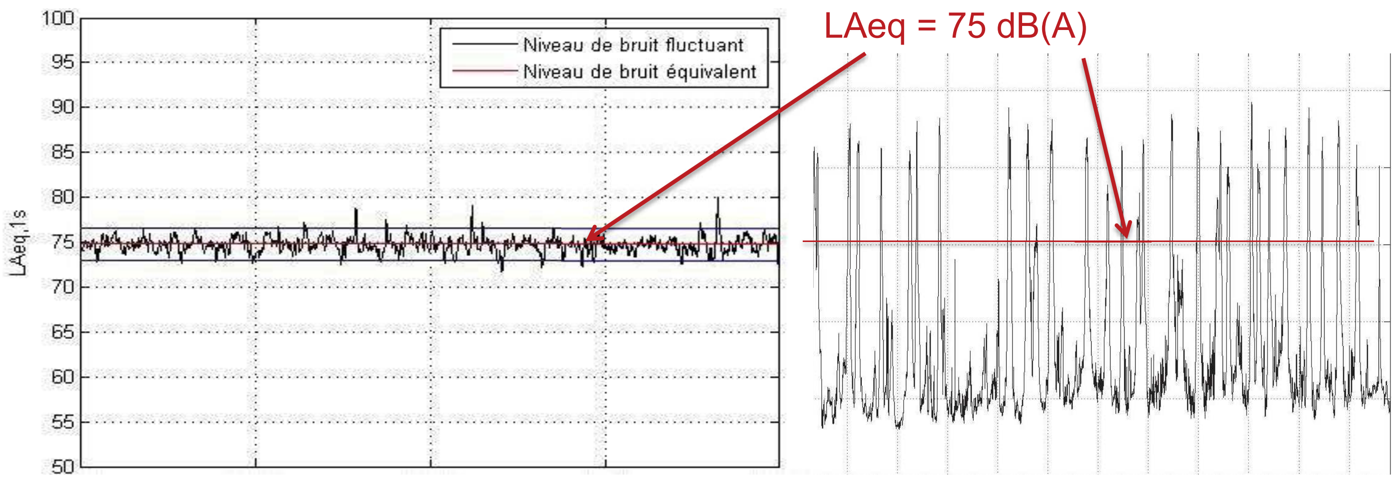
- The decibel unit

  … a logarithmic gymnastics



- 2 different noise exposure situations in terms of perception inhabitants

  …And yet the same score according to the traditional indicators



The Harmonica index: The objectives

- Ease of understanding by the general public

  → scale from 0 to 10 without decibels

- Simple calculation from measured data usually collected by noise measurement devices (LAeq,1s)

- Calculate for one-hour time slots and to derive results over any type of periods

- Closer to the people'perceptions of their noise environment than do the LAeq or Lden indicators

The Harmonica index: 3 stages to construct it

Step 1: Development of proposals of index

Step 2: Consideration of the public's opinion and perceptions

Step 3: Development of the formula of the index

Step 1: Development of proposals for the index

Database containing 24-hour measurement at 24 different sites representing different types of noise exposure (road noise, railway noise, aircraft noise, multi-exposure, urban environments, quiet areas)

60 descriptors calculated from the LAeq(1s) to 1-hour time slots

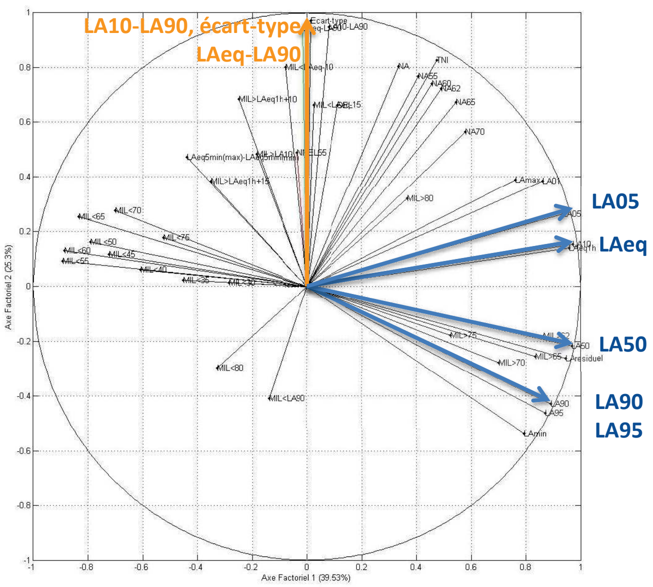
LAeq
Statistical descriptors LAXX, LAmin, LAmax ...
Dynamic descriptors LA10-LA90, LAeq-LA90…
Number of events Nevt > threshold, T > threshold

Principal Component Analysis

allowed to retain 2 major types of descriptors which explain 2/3 of the variance of the data

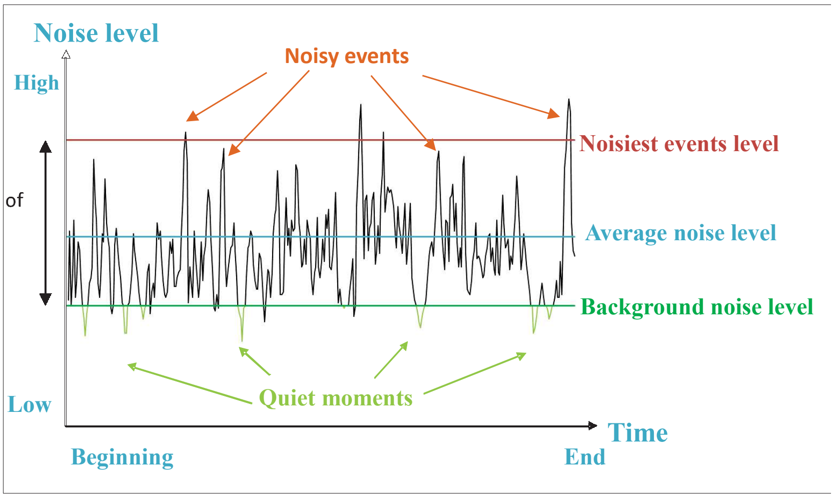
- Average noise descriptors, percentile levels

- Descriptors of the variation of noise related to events



Step 1: Development of the proposals for the index

- background noise
- dynamics of noise
- number of noisy events



- **Proposal 2:**
- periods during which noise levels remain below thresholds (different day, evening, night)

- **Proposal 3:**
- average noise
- background noise
- number and duration of the quiet moments
- level of the noisiest events

- **Proposal 4 (reference) :**
- average noise

Step 2: Consideration of the public's perceptions

Method:

Field questionnaire, face-to-face

among 246 residents or users of public spaces
on 8 different sites (4 in Paris area / 4 in Lyons area)

Laboratory survey with 130 people

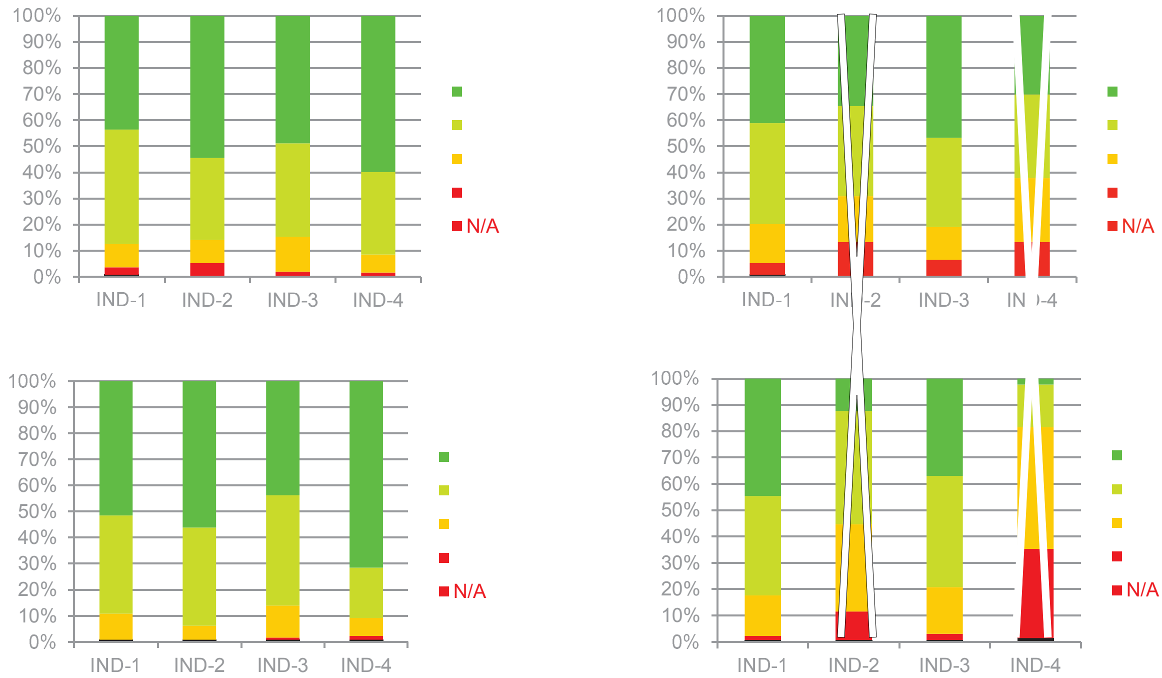
Panel of elected officials, experts and representatives of civil society

Objectives:

- Understand perception in terms of level of noise pollution
- Assess the level of understanding and relevance of the index's proposals

Step 2: Consideration of the public's perceptions

Results of the field and laboratory surveys:



Step 2: Consideration of the public's perceptions

The results of the three surveys match the learnings of the PCA

Concepts/descriptors that seem ‘clearer' to the public:

Background noise, Average noise, Quiet moments, Noisy events

Principle adopted for the formula of the index:

Index = BGN + EVT

- a component relating to the background noise (BGN)
- a component relating to the sound events (EVT)

DYNAMAP
Dynamic Acoustic Mapping

Step 3: Development of the formula of the index

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Method:

Around 350,000 calculated values (24 × 365 days × 40 sites)

Research and testing of the most relevant and robust descriptors for both components of the index: BGN and EVT

Descriptors used for BGN: LA90 eliminated, <u>LA95eq retained</u>
Descriptors used for EVT: LA10-LA90, N_{evt} eliminated, <u>LAeq-LA95eq retained</u>

Calibration of the index’s minimum and maximum values

Index score 0 ←→ very quiet environment: continuous noise 30 dB(A)
Index score 10 ←→ very noisy environment: continuous noise 80 dB(A)

DYNAMAP
Dynamic Acoustic Mapping

Step 3: Development of the formula of the index

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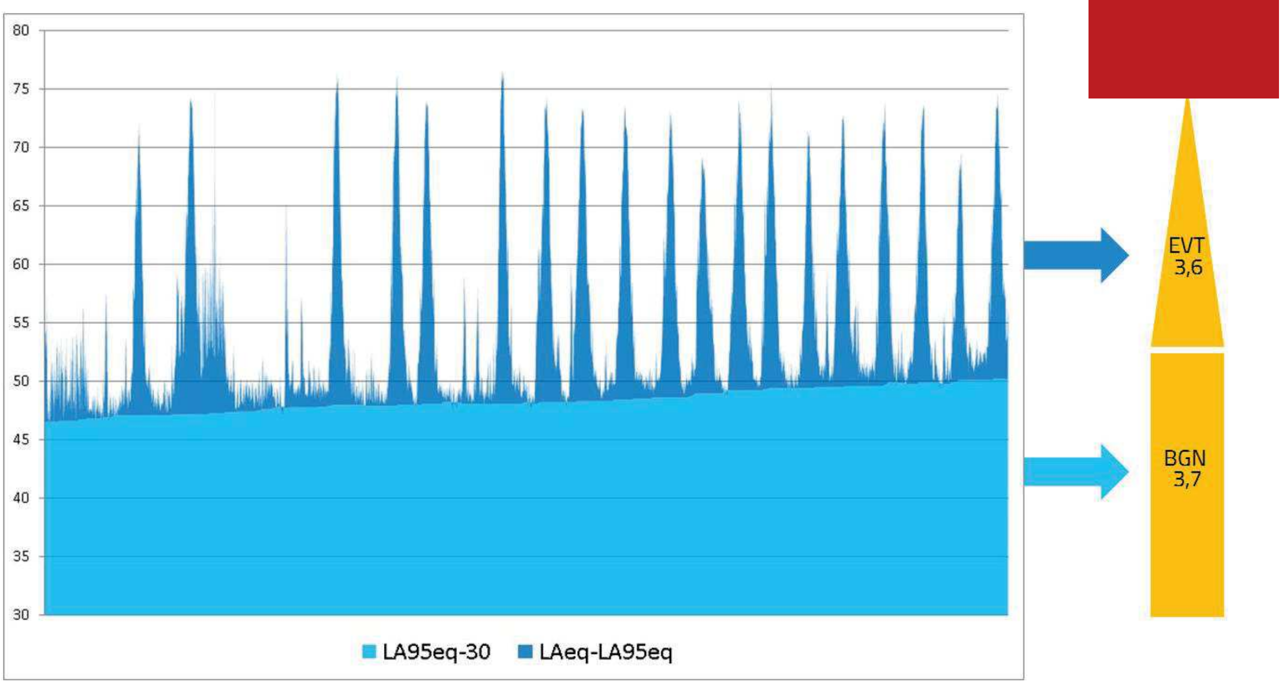
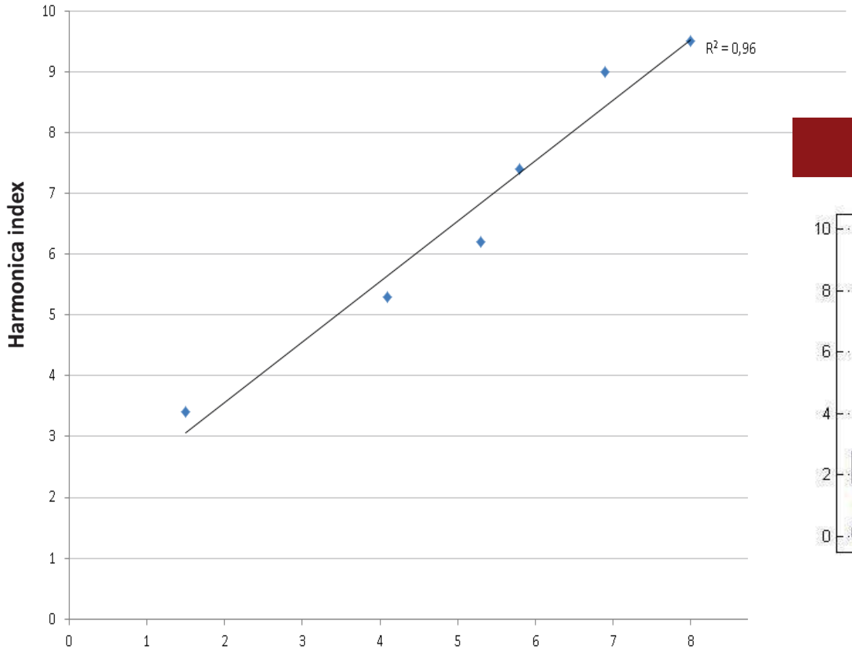
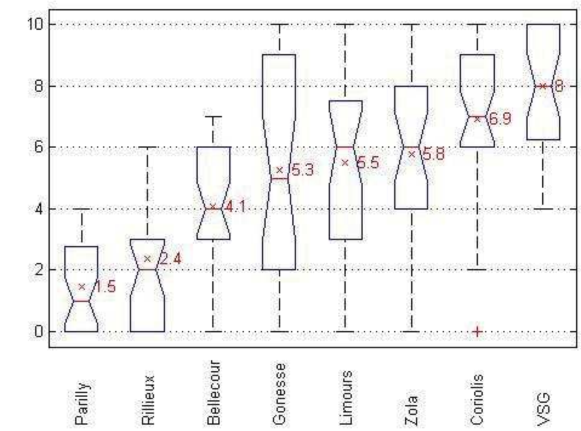


Step 3: Development of the index's formula

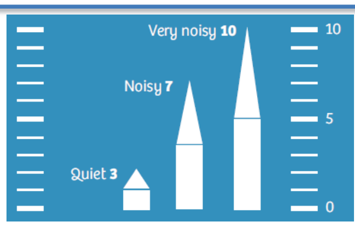
A good correlation between Harmonica index results and perception score given by people during face–to-face surveys



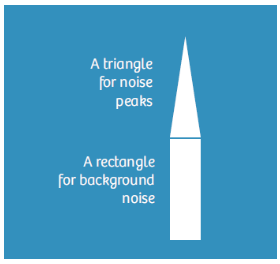


The Harmonica index graphical representation

1 score for the noise pollution level



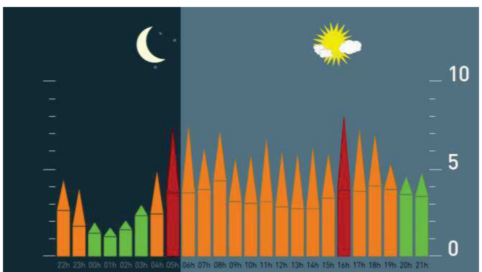
2 shapes to distinguish between the contribution of background noise and noise peaks



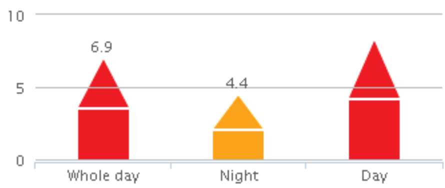
3 colours to indicate the situation compared to the quality objectives or values recognised excessive

Colour	Day from 6 am to 10 pm	Night from 10 pm to 6 am
	between 0 and 4	between 0 and 3
	between 4 and 8	between 3 and 7
	over 8	over 7

4 time periods
hour, day, night, 24h



Example of hourly variation of the index over a 24h period



DYNAMAP
DYNAMIC ACOUSTIC MAPPING

How to test the Harmonica index?

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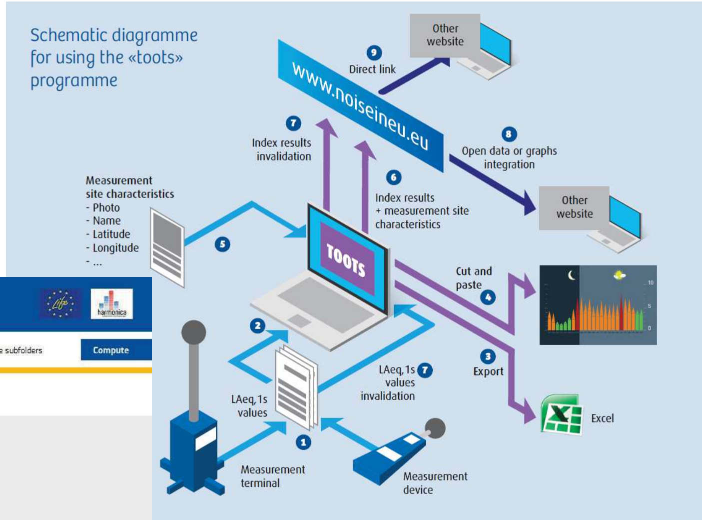
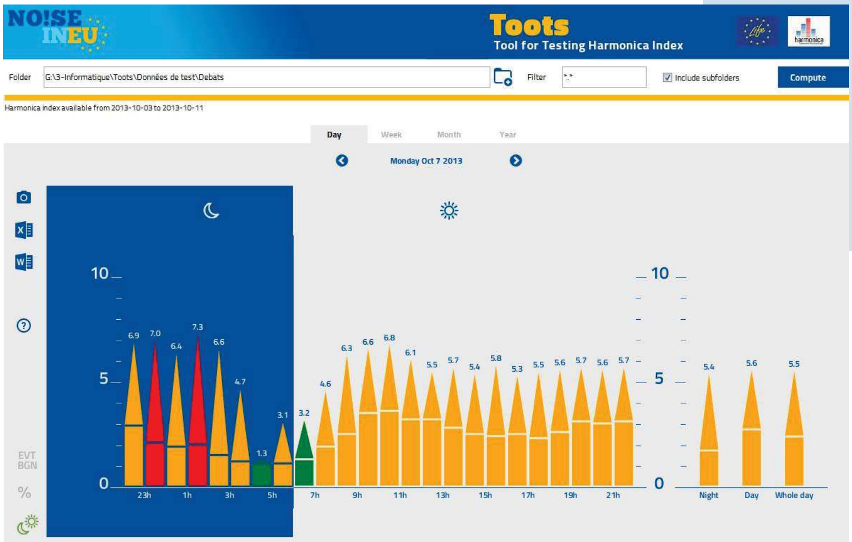
A window program named « Toots » available free of charge
Juste send an email to: join@noiseineu.eu





DYNAMAP
DYNAMIC ACOUSTIC MAPPING

The Harmonica index results platform

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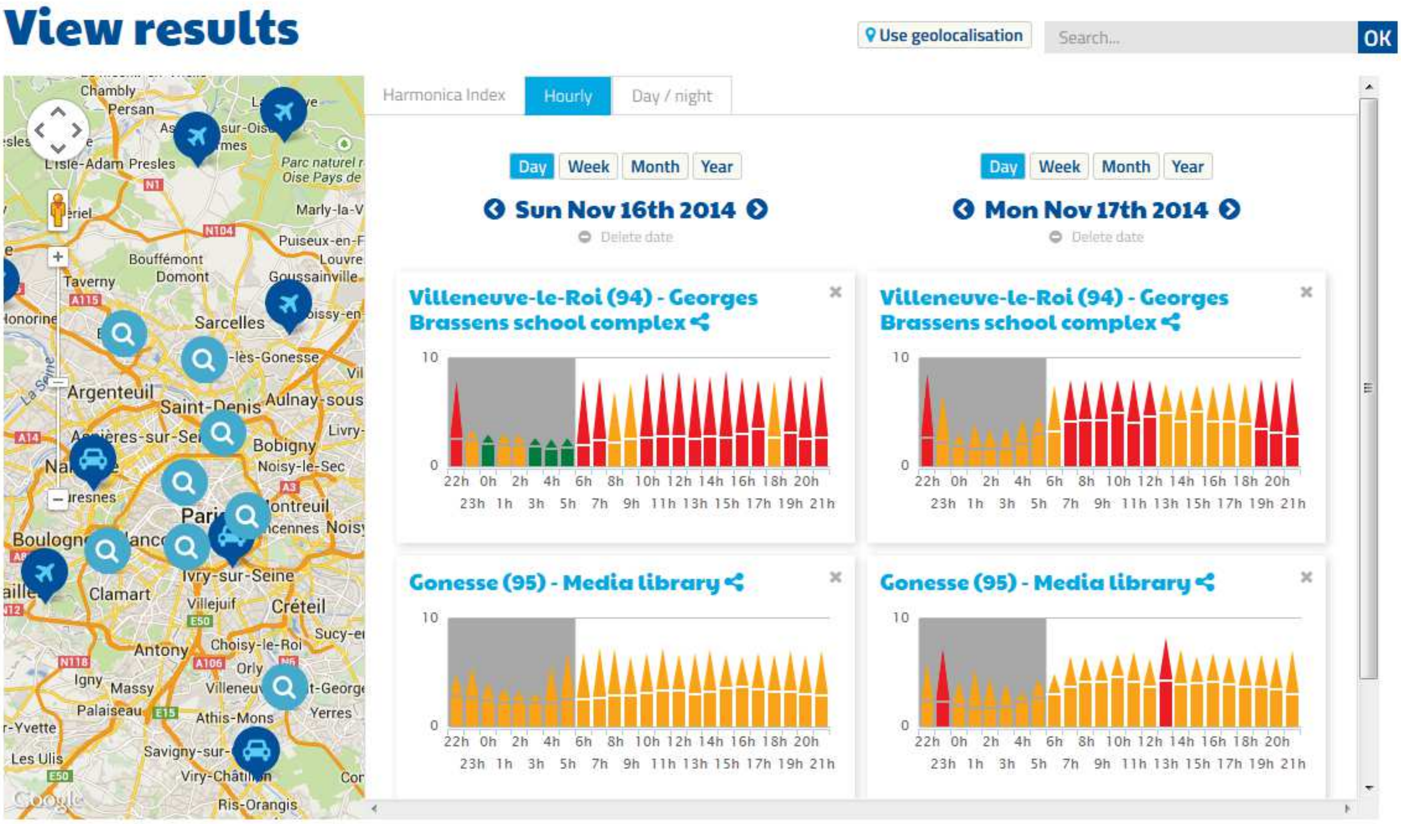
The Harmonica index results platform



The collaborative database of noise abatment actions

The collaborative database of noise abatment actions

PIERREFITTE-SUR-SEINE (93)

Urban requalification of the former RN1 road

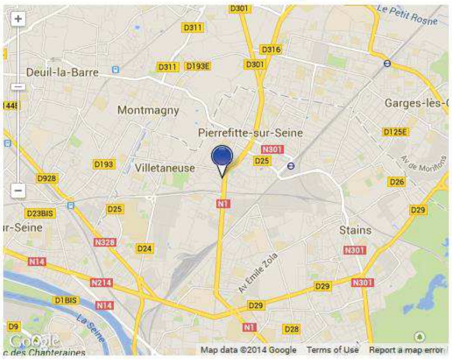
2008-2013

The General council of the Seine-Saint-Denis département completely redeveloped the former RN1 between 2009 and 2013 in order to allow the T5 tramline - which was commissioned at the end of July 2013 - to be laid in the town.

Bruitparif installed a measurement device along this road in Pierrefitte-sur-Seine, in order to measure the change to the acoustic environment related to the redevelopment of this road.

AUTHORITIES

LOCATION



DESCRIPTION

RN1 AT PIERREFITTE-SUR-SEINE AFTER REQUALIFICATION
Bruitparif

Initial evalutation : 9.0 | Final evaluation : 7.9 | Results : -1.1

The fact that the traffic was counted twice on the RN1 - once in July 2008 and once in July 2013 - allowed an in-depth analysis of the noise measurements obtained through the permanent noise measurement terminal Bruitparif had installed along this road in Pierrefitte-sur-Seine.

The comparison of the two periods shows a noise reduction of 1 index point in the daytime (between 6 am and 10 pm) and 1.3 index points at night (between 10 pm and 6 am), making an average decrease of 1.1 points over 24 hours. It is worth noting that the fall can essentially be explained by the event-based component of the index, indicating that the traffic has become more fluid and calm (less noise generated by acceleration/braking and horns, etc.).

Over the same period, the daily flow of traffic has increased by 6 - 7 %. The traffic's speed fell significantly, from 39 to 31 km/h in the daytime and 52 to 40 km/h at night.

The noise reduction can, therefore, be explained by a combination of the following factors:
- Reduction in traffic speed.
- Change in the type of traffic (from stop-start traffic to more "fluid" traffic).
- Changes to vehicles on the road in five years.
- Effect of the change in road surface.

www.noiseineu.eu

NO!SE INEU

EN

NOISE IN EUROPE | THE HARMONICA INDEX | VIEW RESULTS | INITIATIVES | CONTRIBUTORS

Noise pollution is so pervasive in cities that citizens and policymakers tend to believe it is unavoidable.

The Life Harmonica project has developed innovative tools to better inform the public about environmental noise and to help local authorities make the right decisions in fighting noise pollution. These tools include an easy-to-understand noise index, **the Harmonica index** and **a platform** for displaying information about environmental noise in European cities.

This website will allow you to:

- find out more about the Harmonica index
- consult Harmonica index results for various European cities
- discover noise abatement solutions implemented around Europe

If you are a local government representative involved in environmental noise management or you manage a noise monitoring network,

JOIN THE PLATFORM AND CONTRIBUTE!

MEASUREMENT SITES

Saint-Prix (95) - Town hall
VIEW ALL SITES

INITIATIVES

Resurfacing of a 16 km section of the A6 motorway
VIEW ALL INITIATIVES

NEWS

03/04/2015
Toots 1.1, the tool for testing Harmonica index is available for Windows. Click here to know how to get it.

31/12/2014
Download the Layman's report to be informed about tools developed within the Life+ Harmonica project.

09/12/2014
Life+ Harmonica project final event at the Museum of Natural Sciences, Brussels

Links between DYNAMAP and HARMONICA :

Noise measurement network of the DYNAMAP project will **provide data in real time To dynamic noise mapping** .

Noise measurement network can also **address three main challenges (share our experience in Paris region)** :

- **The challenge of understanding phenomena:**
- **The challenge of evaluating actions**
- **The challenge of providing and disseminating information in complement of real time noise mapping by using the HARMONICA index**

Need to storage detailled elementary data : Laeq, 1s (one-second) to be able to recalculate new noise indicators and contribution of events

Links between DYNAMAP and HARMONICA

Noise measurement network addresses those two main challenges :

The challenge of understanding phenomena:

- Better understand the factors that have an influence on noise (traffic conditions, weather parameters, urban fabric, etc.).
- Monitor changes in noise over time relative to changes in technology, travel, social expectations, etc.
- Obtain exposure data for performing epidemiological studies on noise and health or studies on the socio-economic impacts of noise.
- \- Promote an understanding of the effects of transport in terms of noise as well as pollution, its impact on the environment, etc., to make it easier to control and pool these effects.

The challenge of evaluating actions:

- Document the impact of the measures taken on an on-going or occasional basis and evaluate the effectiveness of these actions.
- Anticipate, track and capitalise on knowledge during the implementation of major projects.
- Obtain indicators for tracking the impact of the use of noise criteria in travel and spatial planning policies.

Links between DYNAMAP and HARMONICA

Noise measurement network addresses also this very important challenge :

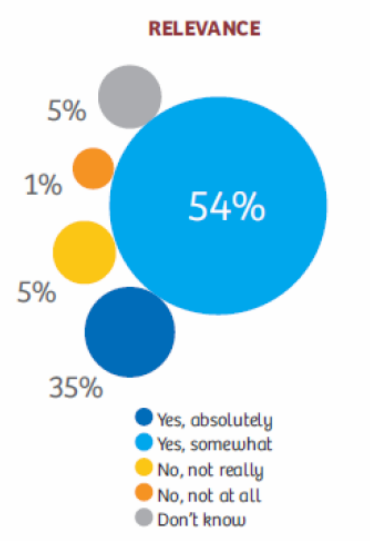
The challenge of providing and disseminating information to the Public :

- Respond to one of the key concerns of residents concerning the quality of their way of life and their health.
- Provide clear, transparent and independent information to the public on the current status of and changes to the acoustic environment ***by using the new HARMONICA index***
- -Provide citizens and the various stakeholders in the fight against noise pollution with the means to understand and analyse noise nuisance.
- Allow for a more precise and targeted quantification of noise exposure than is possible using maps based on modelling.
- Compile statistics on the acoustic environment in the Paris region.

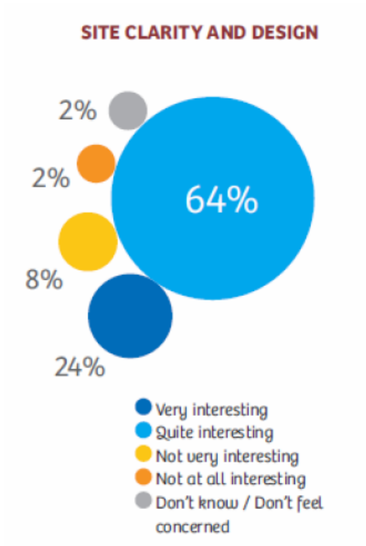
Evaluation by the public

Survey conducted with a questionnaire at the end of the project on 843 people

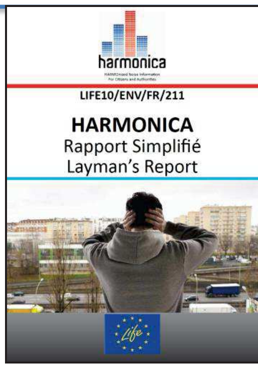
89% of people surveyed
said that **the index is relevant**
and matches their perception of noise

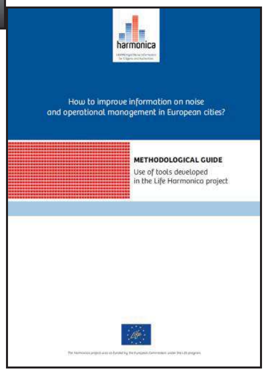


88% of people surveyed
found www.noiseineu.eu **is clear** and well designed



How to participate ?





contact@noiseineu.eu

To become a member of the platform, it couldn't be more simple...

- Publish on the platform the Harmonica index results in your area by simply send a email to: join@noiseineu.eu
- Share the noise abatement initiatives implemented in your area by simply completing the form template, available on the website